TRIP D

STRATIGRAPHY AND STRUCTURE IN THE SOUTHERN TACONICS (RENSSELAER AND COLUMBIA COUNTIES, NEW YORK)*

By Donald W. Fisher
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"The structural [and stratigraphic] investigation of the Taconic region is only in its beginning stages, and....the interpretation of one particular area, to be satisfying, should allow correlations with adjoining areas. In this region of dense underbrush, extensive forests, widespread till cover, low relief, and few fossil localities, facts and observations are hard to accumulate, and their interpretation is beset with difficulties." ---R. Balk (1953)

THE TACONIC SYSTEM

During the early days of the Geological Survey, there was born a controversy which, in modified form, continues today. In the mid-19th century, the argument was primarily stratigraphical and dealt with the age of the rocks east of the Hudson River;in the mid-20th century the argument is primarily structural, dealing with the manner of deformation to account for the present position of these same rocks.

The "Taconic System" was born when E. Emmons (1842) named the deformed shales, quartzites and limestones east of the Hudson River, announcing that they lay unconformably beneath the base of the "New York System" (Upper Cambrian Potsdam Sandstone of present terminology). Later, Emmons (1844) discovered the trilobites Elliptocephala asaphoides and Atops trilineatus (See Plate 2) in deformed strata in western Rensselaer County, and believed that he had found the "Primordial fauna"---the opening chapter of life history of the Earth. Emmons soon became aware of the hostility to his "Taconic System". He said (1855), "In regard to the Taconic System, I do not know that I am indebted to any one for favors, or for suggestions. Indeed, nothing very flattering has ever been said, or published, respecting the views I have maintained on this subject." Although confronted by such formidable opposition as Hall, Dana and Sir Charles Lyell among others, who were unwilling to accept the then novel concept of thrusting or the antiquity of the fossils, Emmons steadfastly maintained that his "Taconic System" was older than Potsdam and correlated it with the Lower Cambrian of Professor Sedgwick of Great Britain. Although Emmons was correct in this thesis, he was incorrect in his resolute view that the entire Taconics were pre-Potsdam, for Bishop, Dana, and Walcott found Trenton fossils at several sites. Meanwhile, S. W. Ford, a Troy jeweler and Prof. W. B. Dwight of Vassar had located several localities where the "Primordial fauna" could be obtained. The bitter controversy lingered long after Emmons' death in 1863. Today, the name Taconian is used as a series name for the Lower Cambrian in acknowledgment of Emmons' recognition of the low stratigraphic position of these rocks.

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GEOLOGIC MAP OF THE SOUTHERN TACONICS

by Donald W. Fisher

(from Geologic Map of New York State, in press)

◻ Selected outcrops

Q - Glacial and alluvial deposits; underlying bedrock geology unknown.

DEVONIAN

- Dha - Kiskatom and Ashokan fms.
- Dou - Onondaga ls. through Esopus sh.
- Dhg - Helderberg lss.
- DS - Helderberg lss. and Rondout fm.

MIDDLE ORDOVICIAN

- Osh - Snake Hill sh.
- Ow - Walloomsac sl.
- Obb - "Berkshire" black phyllite, schist
- On - Normanskill graywacke, sh.
- Oba - Balmville ls.

LOWER ORDOVICIAN AND UPPER CAMBRIAN

- Ob - Lower Ordovician carbonates
- O€s - Stockbridge group (carbonates)
- O€ - Deep Kill, Stuyvesant Falls, Germantown fms.
- €ss - Briarcliff and Pine Plains dols.

LOWER CAMBRIAN

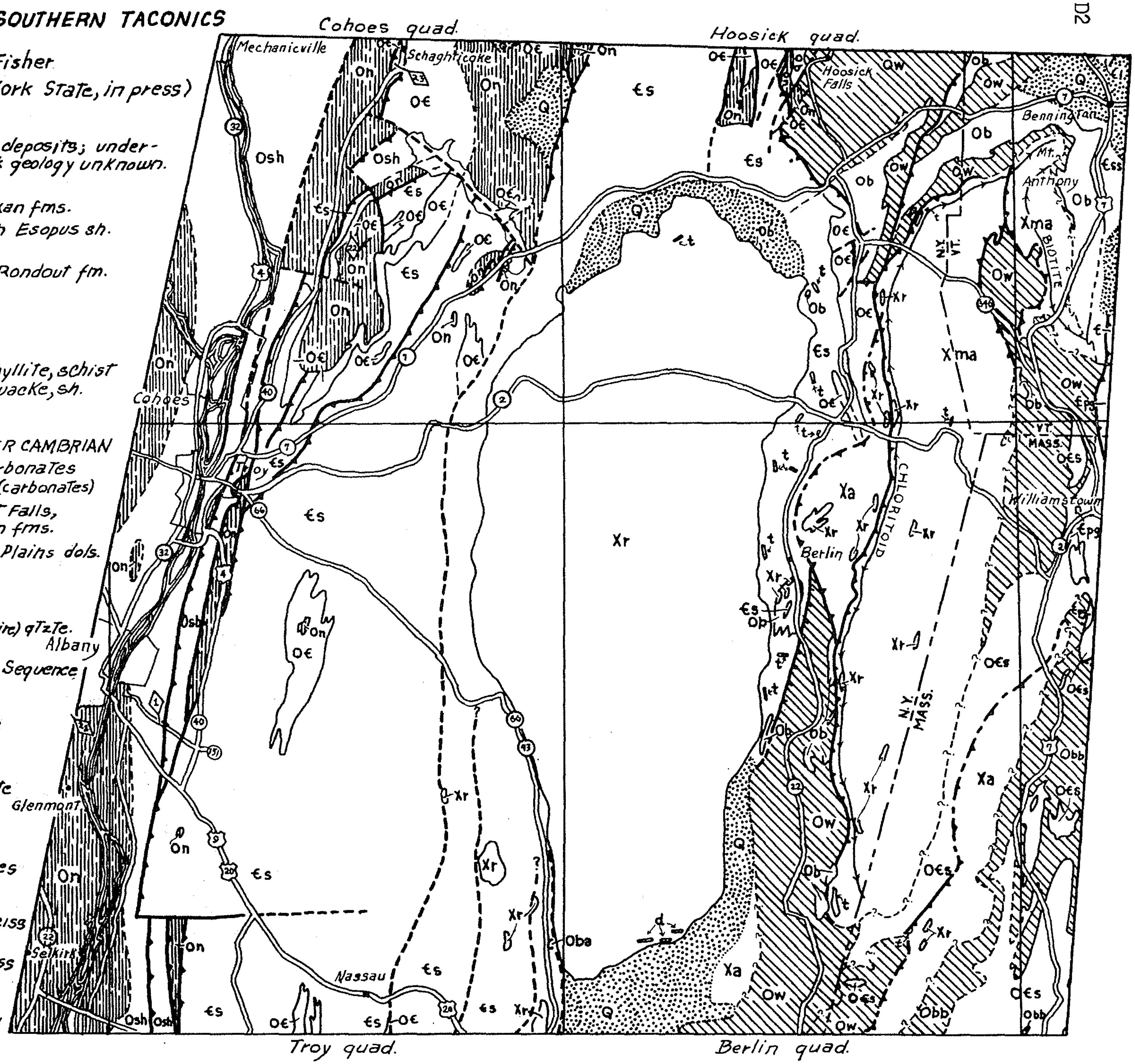
- €l - Carbonates
- €pg - Poughquag (=Cheshire) qtzte.
- €d - Dalton fm.
- €s - Clastics of Taconic Sequence

AGE UNKNOWN

- Xa - Austerlitz phyllite
- Xe - Elizaville sh.
- Xev - Everett schist
- Xma - Mt. Anthony phyllite
- Xr - Rensselaer graywacke
- t - Tuff
- d - Albite-basalt dikes

PRECAMBRIAN

- bg - Biotite granitic gneiss
- bqpg - Biotite quartz plagioclase gneiss
- mu - Metasedimentary rocks, undifferentiated



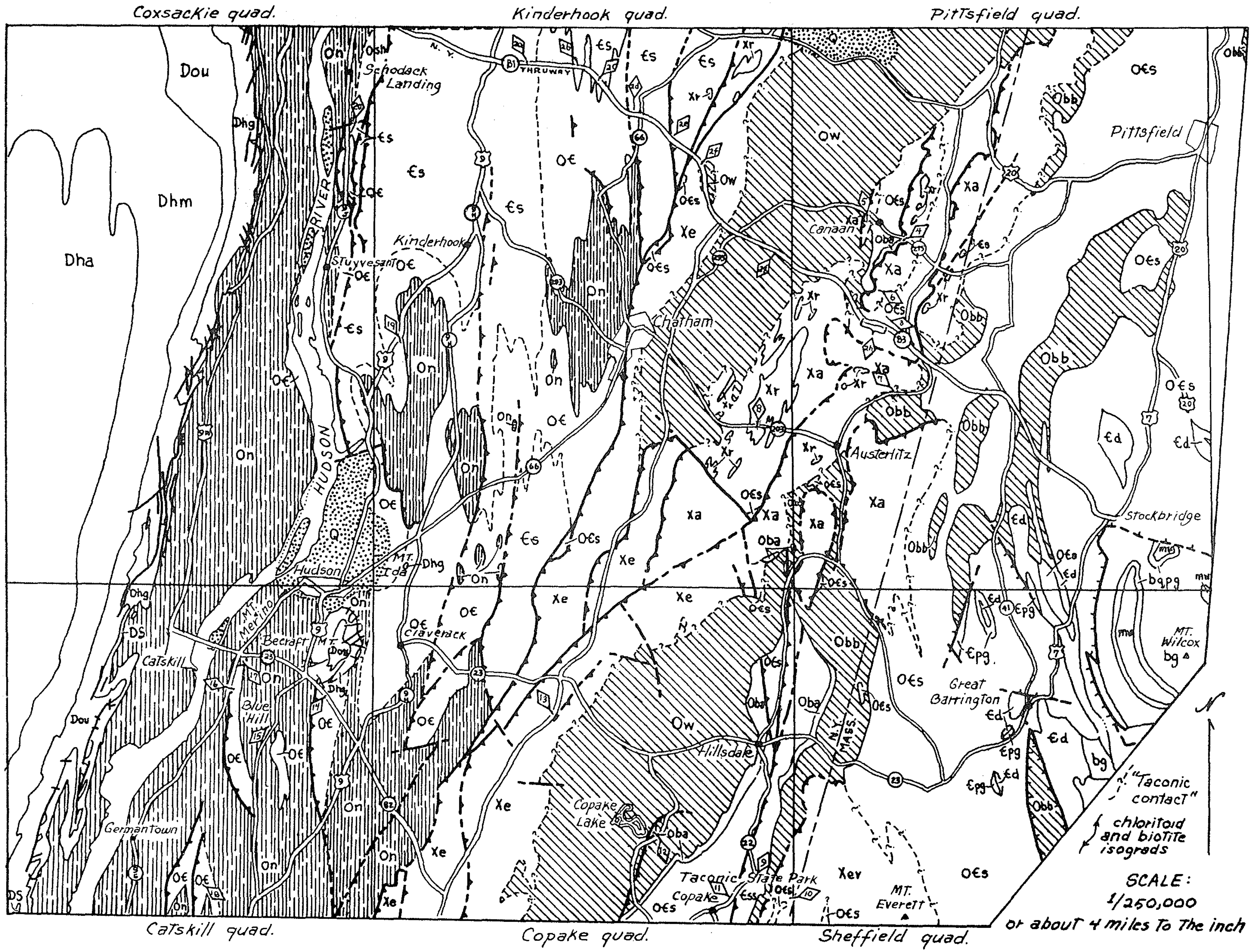

Coxsackie quad.
Kinderhook quad.
Pittsfield quad.
Catskill quad.
Copake quad.
Sheffield quad.
Schodack Landing
Stuyvesant
Kinderhook
Chatham
Canaan
Pittsfield
Austerlitz
Stockbridge
HUDSON RIVER
Hudson
MT. Ida
MT. Merino
Becraft MT.
Catskill
Blue Hill
Claverack
Germantown
Copake Lake
Hillsdale
Taconic State Park
Copake
MT. Everett
Great Barrington
MT. Wilcox
THRUWAY
N.Y.
N.Y. MASS.
"Taconic contact"
chloritoid and biotite isograds
SCALE: 1/250,000 or about 4 miles to the inch

PLATE 1

THE TACONIC PROBLEM

The Taconic Problem is twofold, dependent upon:

(1) establishment of the correct stratigraphic succession, and
(2) formulation of a workable structural device to explain the present attitudes of the rock units.

Excluding a few minor discrepancies, the stratigraphy has been fairly well worked out in all areas despite the meager paleontological control. To be sure, if fossils were numerous in the Taconics, geologic relations would have been clarified long ago. Unfortunately, fossils are exceedingly scarce because of original inhospitable environments, lack of or poor preservation, and eastwardly progressive metamorphism. When found, Taconic fossils can be categorized broadly as (1) Early Cambrian and (2) graptolites. Included in the former are inarticulate brachiopods, trilobite fragments, and fossils of uncertain biologic affinities (see Plate 2)—all difficult to identify. The latter category, the graptolites, (See Plate 3) are also relatively difficult to identify on the species level and the number of paleontologists who are competent to do so are woefully few. Nonetheless, careful scrutiny and ultimate discovery of fossils in Taconic rocks reveals not only relative age but much regarding paleoecology, morphology, and evolution of these Early Paleozoic animals, for "To eyes that have learned to see, fossils are very much alive"....G. G. Simpson.

The Taconic controversy is alive a century after its inception because of the lack of a single structural explanation, satisfactory to all, to account for the present position of the rocks. The failure of some engaged in detailed mapping to venture beyond the borders of their own mapped area, and of others who expound on Taconic geology while possessing only a cursory knowledge of the field relations, has further added to the confusion. Often, workers mapping concurrently in adjacent areas disagree on presence of faults, unconformities, and physical makeup of rock, let alone age of the rocks. The task of the regional compiler is indeed a challenging and frustrating one.

STRATIGRAPHY

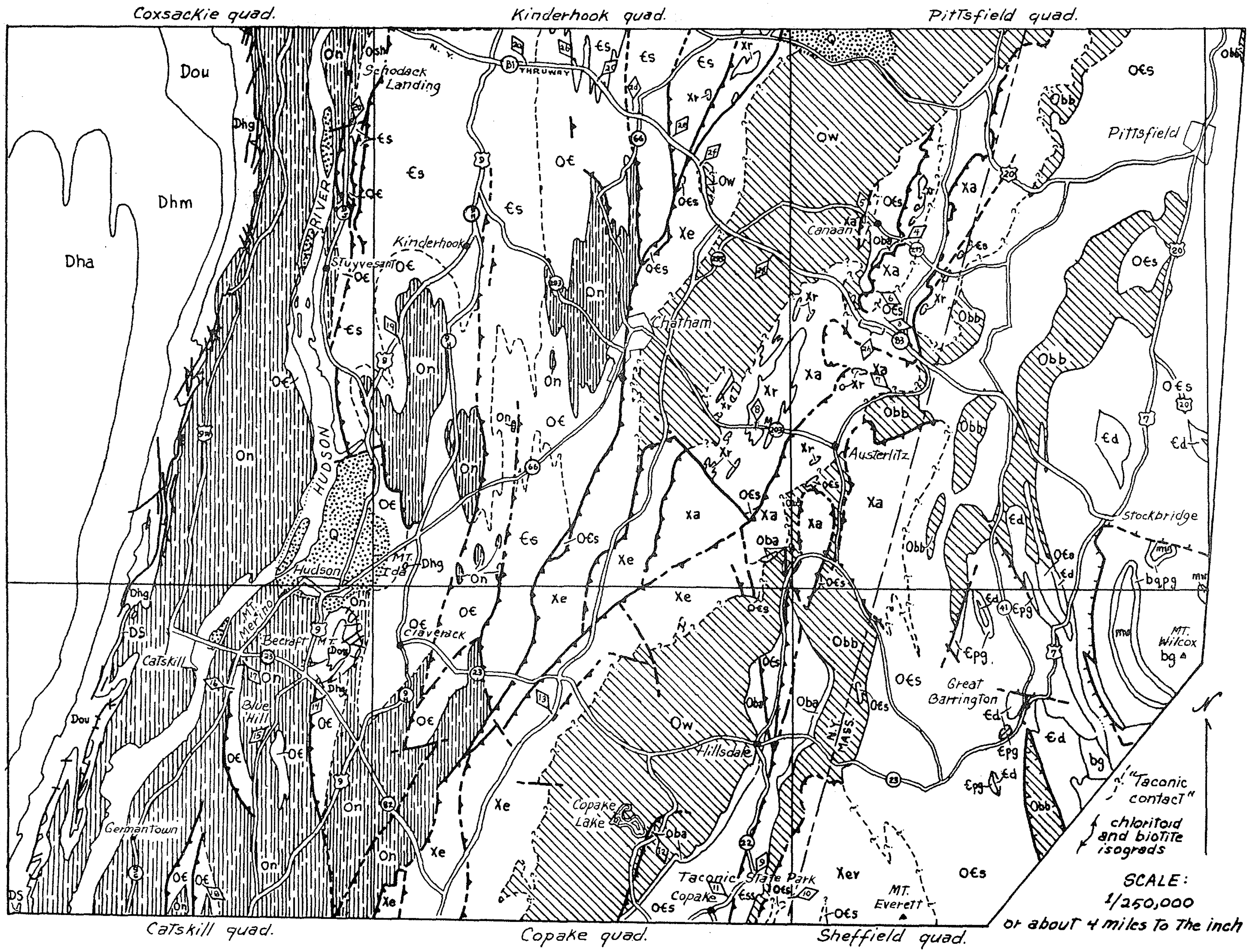
The stratigraphic succession in the southern Taconics has resulted from the work of Dale (1893, 1904), Ruedemann (1914, 1930), Craddock (1957), Weaver (1957) and the unpublished works of Elam, Cutcliffe, Potter, Talmadge, Warthin, and Fisher; that of the northern Taconics by Dale (1899), Keith (1932), Kaiser (1945), Fowler (1950), Zen (1959, 1961), and the unpublished works of Platt, Theokritoff, Shumaker, and Hewitt. For a comprehensive treatment of the stratigraphy of the northern Taconics the reader is referred to Zen (1961).

Following are brief remarks on the recognized units in the southern Taconics. Symbols in parentheses refer to the accompanying geologic map (See Plate 1).

THE EUGEOSYNCLINAL (TACONIC) SEQUENCE

Age Unknown, Probably Lower Cambrian

Rensselaer Graywacke (Xr) - Named by Dale (1893, p. 291), this unit has received more attention than any other in the Taconics primarily because it forms the prominent topographic upland in Rensselaer County and because of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Rensselaer Graywacke (Xr) - Named by Dale (1893, p. 291), this unit has received more attention than any other in the Taconics primarily because it forms the prominent topographic upland in Rensselaer County and because of its unique petrology. It is a first cycle graywacke consisting mainly of quartz, chlorite, and feldspar, with subordinate amounts of mica, tourmaline, zircon, apatite, sphene, garnet, hornblende, and pyroxene. This composition demands derivation from a metamorphic terrane. Customarily, the Rensselaer is medium to coarse textured although locally there is a "conglomeratic" phase of angular quartz and feldspar fragments averaging 3/4" in diameter. Lamprophyres, albite-basalt dikes and tuffs occur within and rimming the Rensselaer Graywacke. Regrettably, exposures of these igneous rocks are rather inaccessible and will not be visited on this trip.

As eastern New York and adjacent states were blanketed by limestones, dolomites, and orthoquartzites (miogeosynclinal deposits) from the Late Cambrian through the Late Devonian, a pre-Late Cambrian age is mandatory-- unless one assumes that the Precambrian Green Mts. were exposed and supplying detritus to the west during the Late Middle or Upper Ordovician. On the west flank of the Precambrian Green Mountain anticlinorium are Early Cambrian carbonates and orthoquartzites having the Elliptocephala asaphoides fauna. Either the Rensselaer is older than these shelf deposits or a western correlative of them. The writer favors the former view.

Whether the Rensselaer is lower Early Cambrian or Precambrian is an academic question dependent upon the placement of the base of the Cambrian System---an unresolved problem at this writing. Some advocate that the base of the oldest widespread olenellid trilobite zone be selected; others that the physical discontinuity between the gneisses of the "basement" and unmetamorphosed sedimentary rocks be selected. The latter course creates special problems in that the physical break is not a time plane. No indisputable fossils have thus far been found in the Rensselaer. Previous workers have variously classed it as Upper Devonian, Middle Devonian, Silurian, Upper and Middle Ordovician, and Lower Cambrian.

Austerlitz Phyllite (Xa) - (new name, Fisher, in press) In the eastern parts of Columbia and Rensselaer Counties is a widespread purple and green to greenish-gray phyllite that constitutes the high north-south ridges. This unit has been named from Austerlitz Township in eastern Columbia County. Chlorite and muscovite are ubiquitous minerals. Along or near the State Line, the Austerlitz assumes a "sandpaper" texture because of abundant coarse dark green chloritoid. Where quartz is abundant, a "salt and pepper" appearance is prominent. Although no fossils have been found, interbedded green chloritic quartzites and subgraywackes coupled with the purple and green color intimates that the unit is a metamorphic phase of the Nassau Formation and transitional with the Rensselaer and Curtiss Mountain units. In the past, the Austerlitz Phyllite has been included in the encompassing term "Berkshire Schist". The black portion of the "Berkshire" is now considered to be Middle Ordovician and it is therefore undesirable to continue using that name. In some, as yet unmapped, areas there appears to be both a vertical and lateral transition of black into green phyllite, so that some of the green, too may be Ordovician.

Elizaville Shale (Xe)- Named by Weaver (1957, p. 739), this unit is a silty, greenish-gray shale or argillite, often laminated and resembling much of the Lower Cambrian Mettawee Formation to the north. In places the cleavage is so pronounced that the formation may be termed a slate. Thin brownish quartzites are common as are black carbonaceous patches along the bedding. The thickness has been estimated at 2000'. The unit is unknown west of the

Chatham Fault. Within the upper Elizaville (and upper Nassau) is a conspicuous ridge-making green chloritic quartzite varying from 10-70' thick which has been named the Curtiss Mountain Quartzite (Fisher, in press). The type locality is on Curtiss Mountain, a conspicuous north-south ridge west of Tackawasick Lake in the Troy quadrangle. This unit is most useful in working out the structure in the southern Taconics. It appears to be a facies between the Nassau, Elizaville and Rensselaer and thus holds a position akin to that of the Zion Hill Quartzite in the northern Taconics.

Everett Schist (Xev) - Named by Hobbs (1897), this is a green quartz-chlorite schist comprising the bulk of the Mt. Washington massif along the New York-Massachusetts line. Foliation is well developed and magnetite octahedra and pyrite cubes are fairly common. This is the highest rank metamorphic rock that we shall see on this trip. Fossils have been completely obliterated if, in fact, they were originally present. Weaver mapped this unit as the Berkshire schist and correlated it with his Middle Ordovician Trentonian black slate to the west. Evidence is conflicting as to whether the Everett green schist is transitional with the black beneath or whether it lies in fault contact or unconformity with it. In the northern Taconics, MacFadyen (1956) called a similar green schist the Mt. Anthony Formation (Upper Ordovician).

Lower Cambrian (Clt)

Bomoseen Subgraywacke - The Bomoseen (type locality at Lake Bomoseen, Vermont) is extensive in the northern Taconics, especially in the west, but poorly developed in the south. It occurs in the Troy quadrangle but is not definitely known further south. It is an olive-green, massive, chlorite-muscovite-albite-microcline quartzite (subgraywacke) with disseminated hematite and graphite and clearly a facies of the Mettawee. Except for the single report of the brachiopod Obolella, fossils are unknown. The Bomoseen will not be visited on this trip.

Mettawee Slate - This unit, named from the Mettawee River in Washington County (Ruedemann, in Cushing and Ruedemann, 1914, p. 69), is a green, purple, variegated green and purple or gray slate or shale. Chlorite and sericite are present in comparatively large amounts. Cleavage is usually well developed and it is the perfection of this feature, together with the uniform physical makeup, which makes the Washington County Mettawee so economically usable as slate flagging. In Columbia County, the Mettawee is predominantly a quartz-silt, greenish-gray argillite with lenticular nodular limestone and limestone conglomerates or breccias having a slump origin (brecciolas) in its upper part. As persistent limestone brecciola, 5-20' thick, in northern Columbia and western Rensselaer Counties is the Stuyvesant Conglomerate (Ford, 1885) an ill-sorted heterogeneous mixture of slabby coarse to fine textured limestone in an argillaceous or quartz-sand matrix--the quartz grains usually well-rounded. The Stuyvesant Conglomerate has afforded most of the Early Cambrian fossils in New York. These include (see Plate 2): the agnostid trilobites, Calodiscus lobatus, C. meeki, Serrodiscus speciosus, Pagetia prindlei, P. connexa, and Pagetides elegans; the olenellid trilobite Elliptocephala asaphoides; the ptychoparid trilobite Atops trilineatus; and the trilobites Fordaspis nana, Kootenia troyensis, Bonnaria salemensis, and Kochiella fitchi. Botsfordia caelata, Obolella crassa and Acrotreta taconica are the most common brachiopods; Helcionella subrugosa is the most frequent gastropod; fragments

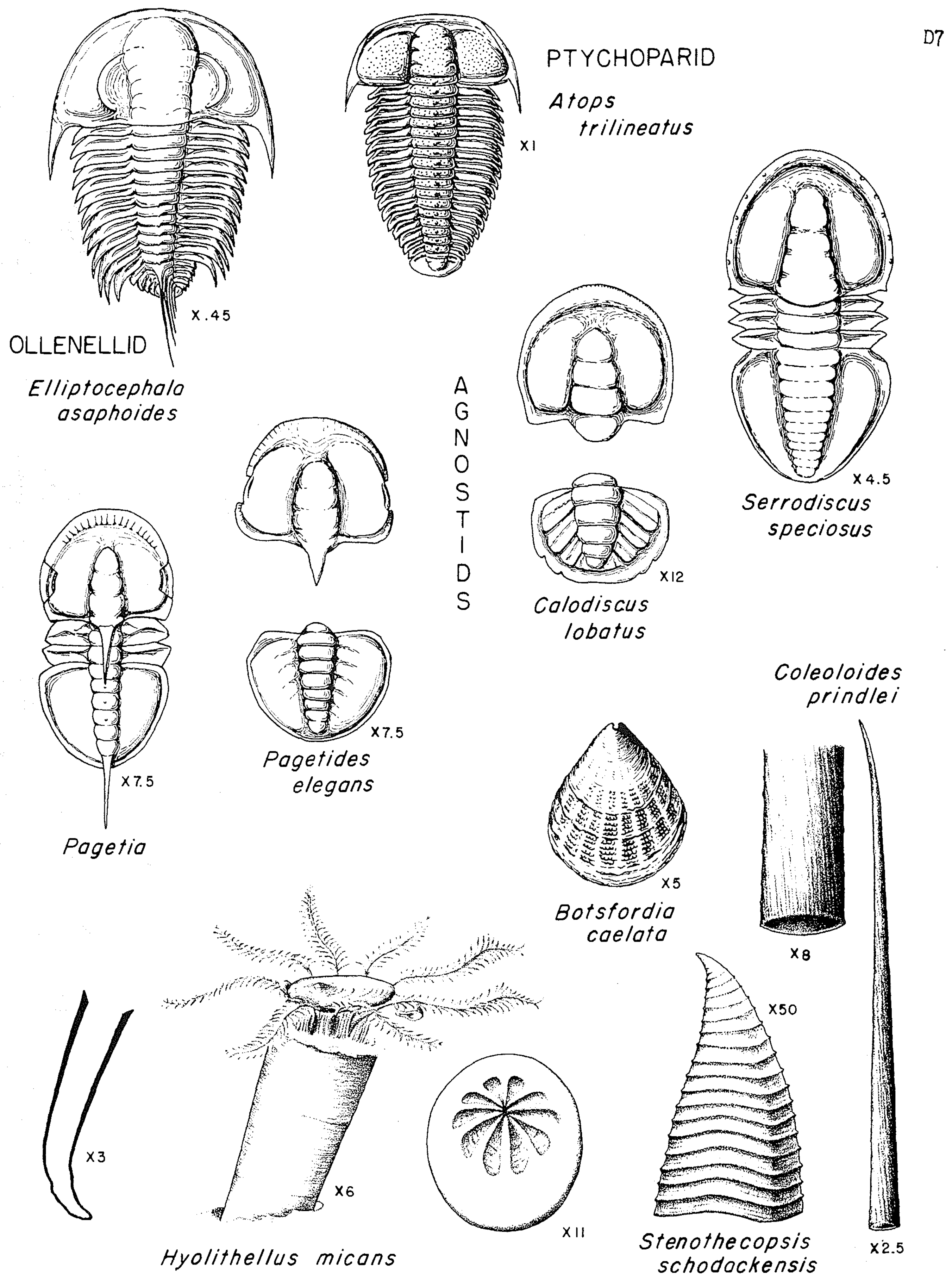


PLATE 2 LOWER CAMBRIAN FOSSILS

of archaeocyathids are locally common. Most Early Cambrian faunas, and this is no exception, are characterized by strange fossils whose systematic position is in doubt as they bear no close resemblance to living animals. In the Stuyvesant Conglomerate these include Hyolithellus micans (a possible tube worm), Coleoloides prindlei (worm? or mollusk?), the hyolithids Hyolithes americanus and H. communis (a probable extinct class of mollusks), Stenothecopsis schodackensis (a possible conularid or phoronid), and Salterella pulchella, Stenothecoides labradorica, and Fordilla troyensis. After lengthy search, most of the above may be collected behind the Troy High School.

Nassau Formation - The name Nassau was given (Ruedemann, in Cushing and Ruedemann, 1914, p. 70) to the intermixed greenish and reddish quartzose shales and interbedded green quartzites so prevalent in southern Rensselaer and northern Columbia Counties. Accessory minerals in the shales include muscovite, chlorite, plagioclase and hematite; those in the quartzites are zircon, tourmaline, and apatite with silica, calcite, dolomite and sericite as cement. The thickness has been estimated as upwards of 800'. The Ashley Hill Limestone (Dale, 1893) with a fauna almost identical to the Stuyvesant Conglomerate, lies within the upper Nassau and therefore fixes its age as Early Cambrian. The Nassau is clearly a quartz-rich facies of the Mettawee.

Schodack?, Hooker?, or West Castleton? Formation - This unit has fallen victim to a nomenclatorial "snafu"---a situation not at all uncommon in stratigraphy. Briefly, the problem is this. Stratigraphically above the Mettawee, or Bomoseen where the Mettawee is missing, are interbedded black shales, usually silty and micaceous, and thin bedded fine textured limestones, locally with thin siltstones, and limestone brecciolas with black chert and buff dolomites. Dale (1899), in Washington County, called this Unit D (Cambrian black slate). Regrettably, Ruedemann (Cushing and Ruedemann, 1914, p. 69) selected the unsuitable geographic name Schodack for this unit, taking the name from known Early Cambrian exposures 2 miles south of Schodack some 75 miles to the south. But these fossiliferous strata are not interbedded black shales and limestones----they are the Stuyvesant limestone conglomerate within the Mettawee green argillite! The name Schodack continued to be applied to the Lower Cambrian black shales and limestones throughout eastern New York until recently, when Theokritoff (1959) advised against its continued use in the northern Taconics. Keith (1923) had called a similar but doubtfully identical unit in Vermont, the Hooker, and Zen (1959, 1961) has lately substituted the name West Castleton for the Early Cambrian black shales and limestones in Washington County and adjacent Vermont. Now, Atops trilineatus and Elliptocephala asaphoides (identified by A. R. Palmer, U.S. National Museum) have been discovered by the writer in black shales and interbedded limestones and siltstones at Judson Point, 9 miles south of the "type" Schodack at Schodack Landing. This, disconcertingly, is the same unit that overlies the fossiliferous Mettawee at Schodack Landing and therefore, ironically, Ruedemann was indeed correct!

North of Oakwood Cemetery, North Troy, there is about 30' of rather massive tan to pink ferruginous calcareous sandstone or quartzite which Ruedemann (Cushing and Ruedemann, 1914, p. 70) named the Diamond Rock Quartzite; its meager poorly preserved fauna indicates an Early Cambrian age. It has not been positively identified outside of the type locality. The Diamond Rock overlies the Mettawee and underlies the inadequately defined "Troy" shales, which probably are, in part, the "Schodack" black shales and limestones and Mettawee shales.

Upper Cambrian and Lower Ordovician (O€)

In the Taconic Sequence are Upper Cambrian (Croixian) and Lower Ordovician (Canadian) clastics, which, in the northern Taconics, are separable into the Hatch Hill and Poultney Formations, respectively. These lithologies change southward so that extension of these names is impractical. In northern Rensselaer County, the Lower Ordovician Schaghticoke (pronounced skat-i-coke) and Deepkill formations with their diagnostic graptolite faunas of Dictyonema flabelliforme and Staurograptus dichotomus on the one hand and Tetragraptus, Phyllograptus and Didymograptus bifidus on the other, are classic (see Plate 3). However the names Schaghticoke and Deepkill have assumed a time connotation and although their lithologies extend into Columbia County, it is felt unwise to use these names for lithic units in the southern Taconics owing to the time-transgressive nature of the units, for example the Schaghticoke lithology (Early Ordovician at its type locality) is apparently Late Cambrian in Columbia County. Accordingly, the new names Germantown and Stuyvesant Falls have been proposed (Fisher, in press) for Late Cambrian and Early Ordovician rocks in the southern Taconics. The Germantown consists of ribbon limestones, thin siltstones, brecciolas, and interbedded black shales bearing Callograptus and Dendrograptus, which, to W. B. N. Berry suggest a Late Cambrian age. Overlying the Germantown with a sharp lithologic change is a sequence of interbedded green fine textured argillite which has produced the graptolites Tetragraptus, and Didymograptus south of Becraft Mountain. The Stuyvesant Falls Formation is at least 400' thick at its type locality in Kinderhook Creek at Stuyvesant Falls where it underlies the Mt. Merino shale of the Normanskill. Complete sections of the Germantown Formation are unknown and its base is obscured within the black shale-limestone terrane. It is probably no less than 400' thick.

Middle Ordovician

Normanskill Group (On) - Within the Taconic Sequence resting unconformably upon clastics of varying ages is a succession of shales and graywackes about 2000' thick. The basal unit (called the Indian River Slate in the northern Taconics) is a green or red shale or slate locally with green chert or siliceous argillite. The medial unit (Mt. Merino black shale and chert) is the most graptoliferous with many genera represented, while the upper unit (Austin Glen Graywacke) is composed of tan weathering graywacke interbedded with gray and black shales. The graywacke is composed principally of angular quartz and shale fragments in a calcareous argillaceous matrix. Plagioclase feldspar is subsidiary. Nemagraptus gracilis is characteristic of the Mt. Merino and Climacograptus bicornis is characteristic of the Austin Glen (see Plate 3). No younger rocks are known within the Taconic Sequence. Prof. W. B. N. Berry, University of California, has recently restudied the graptolite faunas of the Normanskill and older shales, and in so doing, has discovered many new fossil localities. Some of his revisions have appeared in print (Berry, 1960).

THE MIOGEOSYNCLINAL SEQUENCE

Poughquag (=Cheshire) Quartzite (€p) - The name Poughquag was given by Dana (1872) to the basal quartzite holding the Elliptocephala fauna and resting on the Precambrian gneisses. Later, Emerson (1892) applied the name

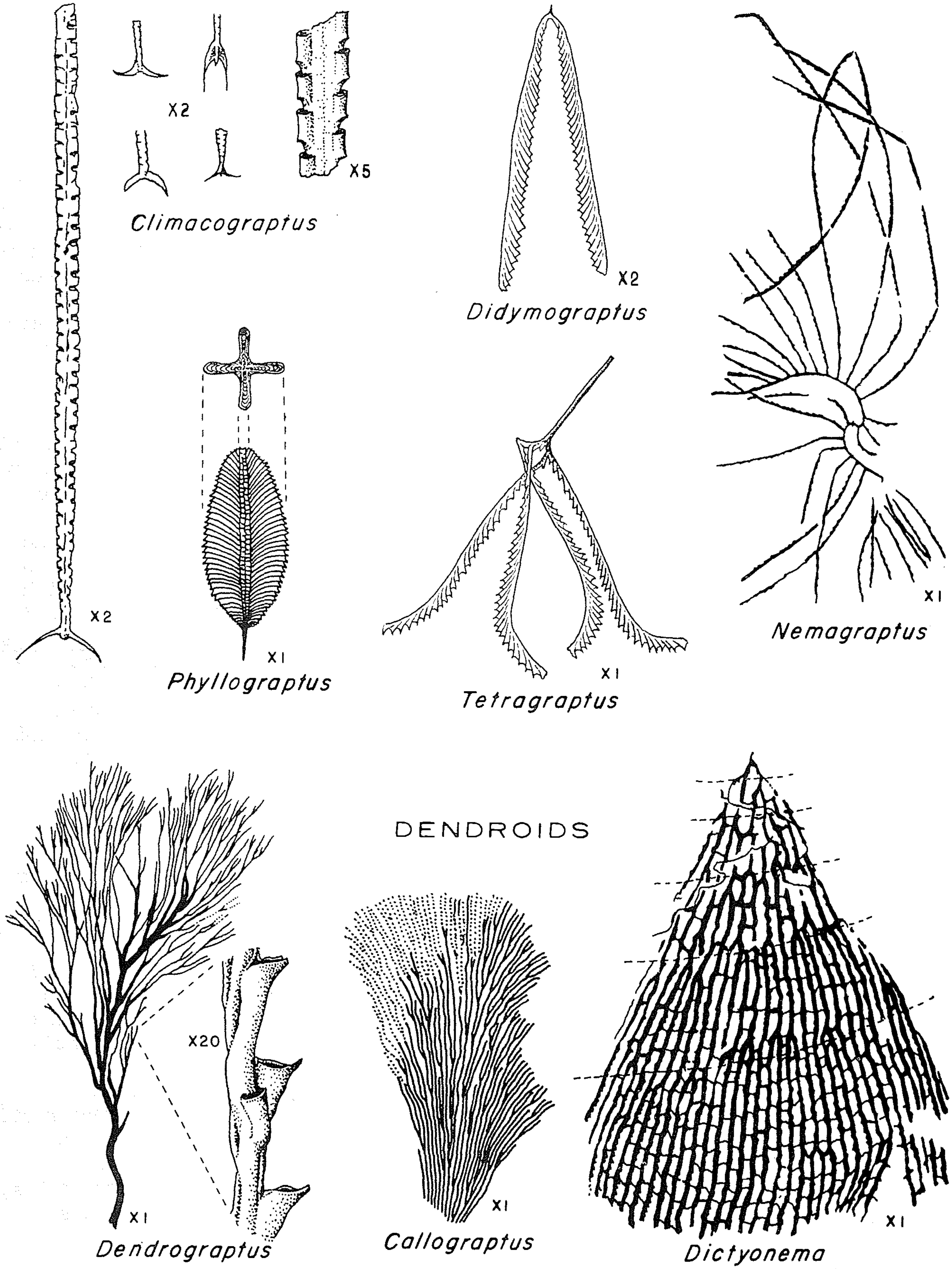


PLATE 3 GRAPTOLITES

Cheshire to the same unit in western Massachusetts and Vermont. The Poughquag is a fine to medium textured virtreous to conglomeratic quartzite, feldspathic at its base and usually brownish to white in color. In New York State it is not known to outcrop north of Stissing Mountain, Duchess County.

Stockbridge Group (O€s) - The name Stockbridge was given (Emmons, 1842, p. 154) to the carbonates above the basal quartzite (Poughquag) and beneath the Berkshire schist (black portion only), thus ranging from Early Cambrian through lower Middle Ordovician. Stockbridge is synonymous with the later term, Wappinger (Dana, 1879). In places, the Stockbridge has yielded fossils. This has led to a critical examination of the subtle lithologic differences within the carbonate terrane and has permitted the following subdivision, in ascending order:

Stissing Formation (€l) - In discovering *Hyolithes billingsi*, *Paterina stissingensis* and *Prozacanthoides stissingensis* at Stissing Mountain, Dwight (1890) announced what he thought were Middle Cambrian fossils. The last to work in that area (Knopf, 1946) regarded this unit as wholly Lower Cambrian. The Stissing Formation consists of a lower dolomite with *Hyolithellus micans*, an intermediate red dolomitic shale and argillaceous dolomite and an upper bluish-gray cherty dolomite and limestone with the fossils which Dwight reported. The Stissing may be present in southern Columbia County.

Pine Plains Formation (€ss) - Sandy dolomites, shales, sandstones, oolites; no fossils except the algae *Cryptozoon*; Upper Cambrian but may be older; Knopf (1946) reports at least 1300' thick.

Briarcliff Dolomite (€ss) - Vuggy, light colored dolomite, slightly sandy. The occurrence of the trilobites *Plethometopus*, *Plethopeltis* and *Prosaukia* confirm a Late Cambrian (Trempealeau) age; Knopf (1946) reports at least 1000' thick.

Halcyon Lake Calc-dolomite (Ob) - Fine to medium textured calcareous dolomite and dolomitic limestone with the nautiloids, *Ectenoceras* and *Ellsmereoceras*, and the gastropods, *Ozarkispira* and *Sinuopea*, all indicative of an Early Ordovician (Lower Canadian) age; about 300' thick.

Rochdale Limestone (Ob) - Limestones, dolomites, rarely sandy; the gastropod *Lecanospira compacta* is most abundant, also has nautiloids *Dwightoceras*, *Eothinoceras* and *Vassaroceras* and the trilobite *Hystricurus conicus*, all guides to the Early Ordovician (Middle Canadian); about 400' thick.

Copake Limestone (Ob) - Dolomitic limestones, calcareous dolomites with 80-90' of cross-bedded sandy dolomite in the basal portion; 212' at type locality at Tom Hill at Copake, Columbia County; has with brachiopod *Syntrophia lateralis*, the gastropod *Ecculiomphalus volutatus* and the trilobite *Isoteloides* cf. *whitfieldi*, all denoting a correlation with the Upper Canadian Fort Cassin Formation of the Champlain Valley.

Balmville Limestone (Oba) - Named by Holzwasser (1926, p. 40) from the very fossiliferous outcrop at Balmville, two miles north of Newburgh, N. Y., where it is 70' thick, it unconformably rests on various divisions of the Stockbridge. The Balmville is a detrital limestone, commonly conglomeratic (calcirudite) or coarse textured (calcarenite) but usually medium (calcisiltite) to fine textured (calcilutite); sometimes it is an argilli-calcilutite. Fossil fragments are relatively common (as rocks east of the Hudson River go) with pelmatozoan ossicles and columnals most obvious. Less frequently, sections of brachiopods, gastropods, horn corals and bryozoa can be seen. Faunal lists have not been published for Columbia County, but in Duchess and Ulster County the Balmville has yielded the following: the algae Solenopora compacta; the corals Lambeophyllum and Tetradium; Receptaculites; the bryozoans Arthropora armatum, Batostoma winchelli, Eridotrypa aedilis, Helopora divaricata, Phyllodictya varia and Rhinidictya mutabilis; the brachiopods Dinorthis pectinella, Nicollella, Paucicrura, Rafinesquina alternata and Sowerbyella; unidentified endoceroids; and the trilobites Flexicalymene senaria and Illaenus crassicauda. The abundance of echinoderm debris requires a post-Canadian age. This fauna seems to agree most closely with the Rockland and Black River limestones (Amsterdam, Chaumont) of the Mohawk and Black River Valleys. In Columbia County, the Balmville occurs in fault blocks (horses) and in normal stratigraphic position.

Walloomsac Slate (Ow) - Named by Prindle and Knopf (1932, p. 269), this is a black slate or black phyllite which occupies large areas in eastern Rensselaer and eastern Columbia Counties. It is conformable with the Balmville and disconformable on older portions of the Stockbridge Group. It likewise rests on the Elizaville Shale but the nature of this juncture is disputable. Similarly, the Walloomsac's upper contact is in dispute. Previously mapped by Craddock and Weaver (1957) as Trentonian black slate, the Walloomsac can be traced southward into the Rhinebeck quadrangle into the graptolite-bearing Mt. Merino portion of the Normanskill. Potter (unpubl.) has demonstrated that the Walloomsac of the Hoosick quadrangle grades laterally into the Mt. Merino and Austin Glen units. Occasional thin beds of limestone may be found within the lower portion of the Walloomsac. Fossils have not been found in the Walloomsac of Rensselaer and Columbia Counties. Striated cleavage planes are common as are pyrite crystals and white quartz veins. An estimated thickness of upwards of 1000' has been reported for Columbia County.

Snake Hill Formation(Osh) - The type locality is at Snake Hill on Saratoga Lake where the characteristic quartz-silt gray-black shales and thin calcareous siltstone beds occur. The Snake Hill is a facies of the Normanskill of the Hudson Valley and the Canajoharie black shale of the Mohawk Valley. The fauna consists primarily of graptolites in the shales and brachiopods and pelecypods in the siltstones.

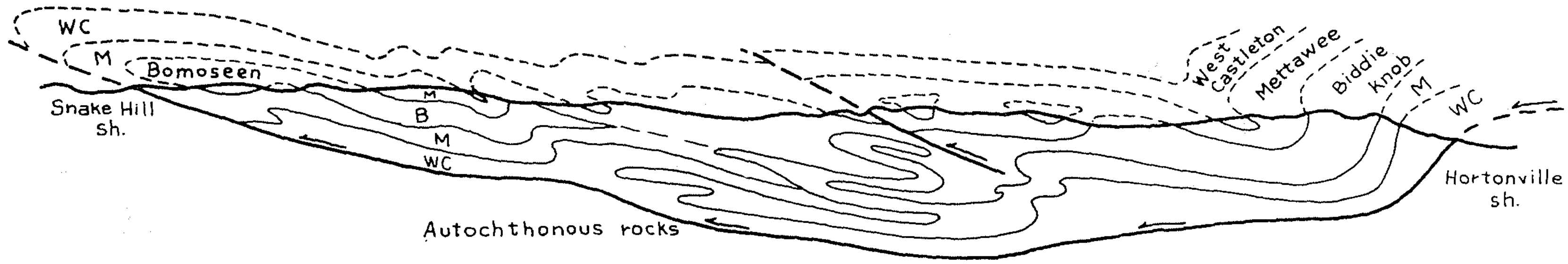
East of the Hudson River and within the Snake Hill Formation is a north-south linear agglomeration of a slump blocks of fossiliferous limestone, dolomite, shale and graywacke termed the Rysedorph Conglomerate. Its fauna was fully described by Ruedemann (1901) and has been much quoted because of its uniqueness. The Rysedorph seems to represent the spalling off of a thrust plate (gravity slide) during its westward travel into the then unconsolidated Snake Hill sediments.

To the north, in the Schuylerville, Cambridge and Fort Ann quadrangles, are larger exotic blocks of Trenton and Canadian carbonates collectively known as the Bald Mountain Limestone (Ruedemann, in Cushing and Ruedemann, 1914). Various interpretations have been offered to account for their presence. One of the more logical appears to be that the carbonate represents a block caught between two proximal eastward dipping reverse faults. Slump blocks exist to the west of the carbonate sliver within the Snake Hill formation. Numerous other Trenton and Canadian carbonate blocks (horses) occur along reverse faults elsewhere in the Taconics, for example the carbonates at Rock City School on the Kinderhook quadrangle, and the Tackawasick Limestone at the west edge of the Rensselaer Plateau in the southeast corner of the Troy quadrangle.

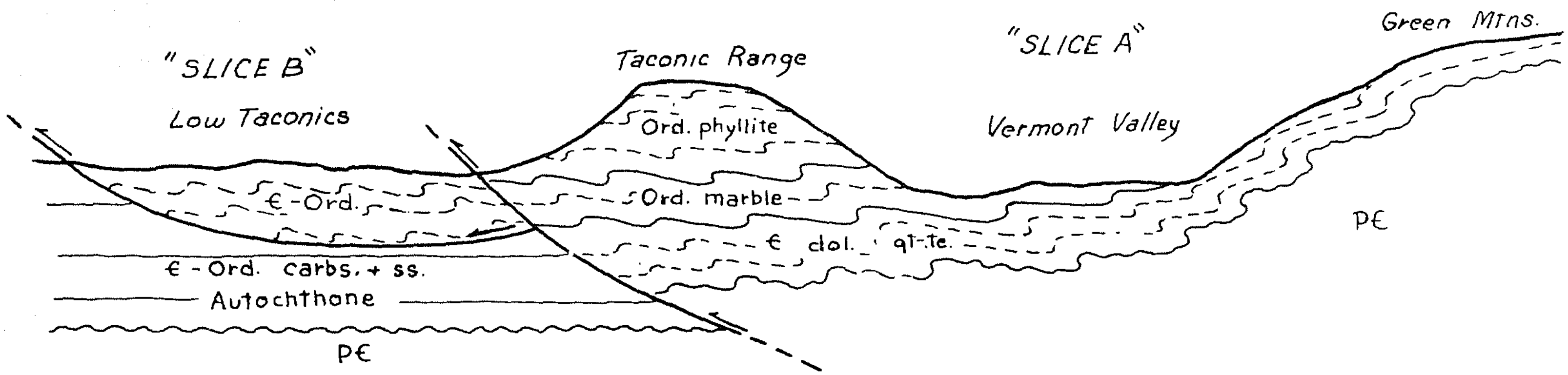
STRUCTURE

The major structures in the Taconics are lengthy essentially N-S reverse faults and paralleling pene-isoclinal folds overturned to the west with much of the folding doubly plunging both to north and south. The N 10° - 15° E trend of some of the major faults (notably the Chatham Fault) truncate the N-S post-Normanskill folds. Transverse east-west tear faults are less common as are symmetrical folds. Of the minor structures, cleavage is the most prominent. Naturally, it is conspicuous in the shales but it is also obvious in the Balmville Limestone and an irregular cleavage can be detected in many dolomites accounting for the rugged appearance of weathered surfaces. East of the Chatham Fault, cleavage sharply increases and masks bedding so effectively that the amount and direction of folding is exceedingly difficult to determine.

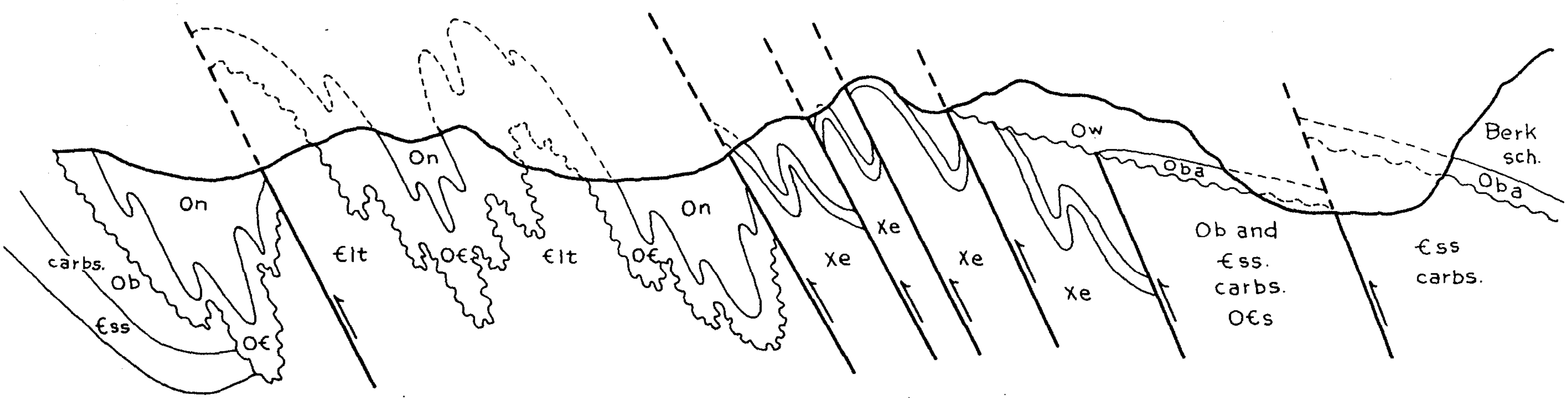
As with fossils, metamorphism (even low rank) is disastrous to primary features. Nonetheless, there are three types of sedimentary structures which can be utilized with some confidence in distinguishing between top and bottom of bedding. Small-scale cross-bedding is most reliable and occurs in the thin siltstones, calcareous sandstones and sandy dolomites. This criterion has proved serviceable in the Nassau, "Schodack", Germantown, Stuyvesant Falls, Austin Glen and parts of the Stockbridge units. Flow casts on the bottoms of beds are reliable but less frequent. They are exceedingly abundant in the Stuyvesant Falls Formation and less abundant in the Rensselaer, Nassau, Curtiss Mountain, "Schodack", Germantown, Austin Glen and Pine Plains units. Graded bedding in the Rensselaer, Stuyvesant, Germantown, Austin Glen and Stockbridge units must be used with caution. Micro-graded bedding is trustworthy but large-scale graded bedding occasionally gives contradictory results. Ripple marks are too rare to be of much help.



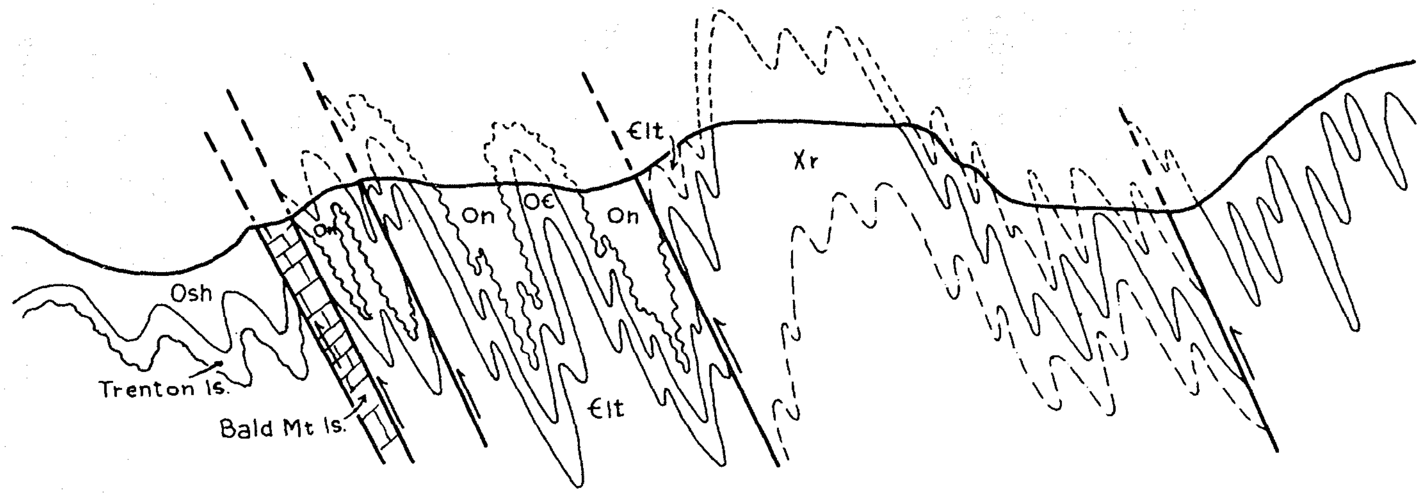
(A) ALLOCHTHONE OR KLIPPE HYPOTHESIS



(AA) P. C. HEWITT HYPOTHESIS



(B) BUCHER HYPOTHESIS



(C) C. LOCHMAN *IN SITU* HYPOTHESIS

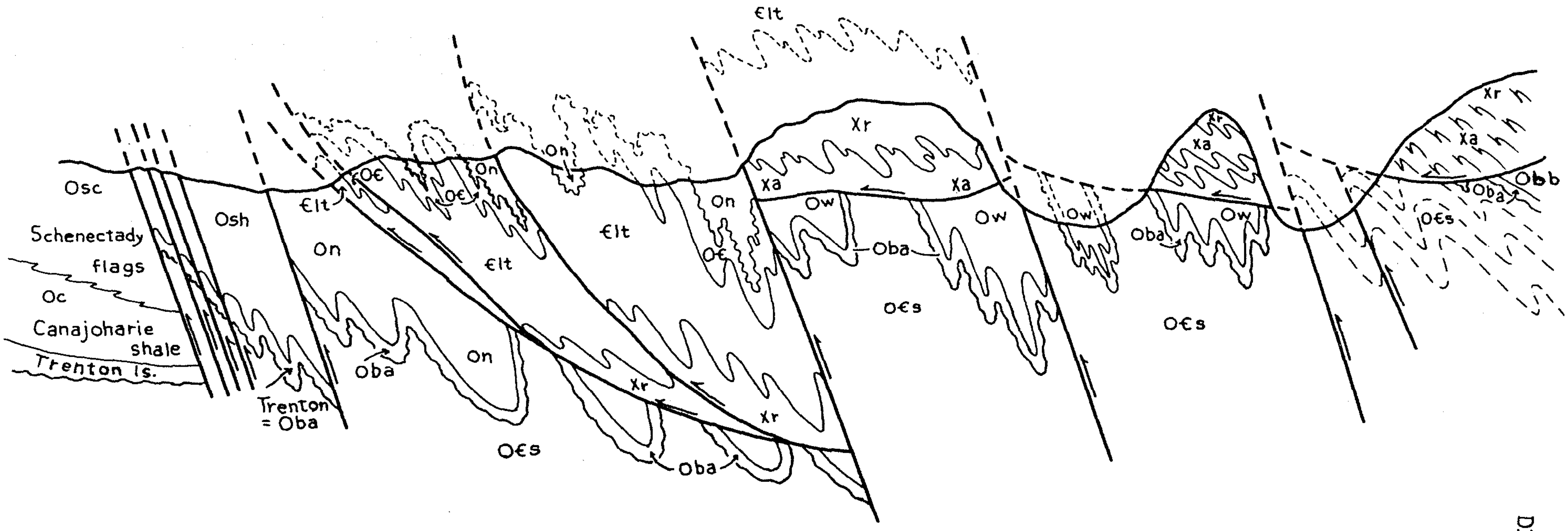


PLATE 4 (D) D. FISHER INTERPRETATION OF COLUMBIA COUNTY

THE TACONIC PROBLEM CONTINUED:

HYPOTHESES PROPOSED TO EXPLAIN THE FIELD RELATIONS

The Taconic Sequence is a succession of clastics, primarily micaceous and quartz-silt shales, purple and green shales and slates, red slates, quartzites, graywackes, and interbedded black shales and ribbon limestones, having relatively great north-south extent (ca. 150 miles) and relatively small east-west extent (ca. 25 miles). Lamprophyres, dikes of diabase and albite-basalt, and tuffs occur within it. Clearly, this is a eugeosynclinal suite. Peripheral to the Taconic Sequence are contemporaneous miogeosynclinal carbonates and orthoquartzites. In order to explain the apparent anomalous position of the Taconic Sequence, differing structural hypotheses have been proposed and it is these that are the source of current controversy.

All workers recognize a western bounding fault or zone of faults, usually termed "Logan's Line" although it properly should be called Emmons' Line for it was he who first recognized it! However, the nature of the eastern boundary is cause for dispute. This "Taconic Contact" holds the key to the Taconic Problem. When exposed, which is seldom, the field relations are inconclusive for the increased metamorphic rank of initially similar lithologies only obscures the character of the eastern contact. In addition, fossils are absent in these metamorphic rocks. Different workers see this eastern boundary as a fault, unconformity, conformable contact or transitional contact....some workers are noncommital.

Fundamentally, three hypotheses exist which attempt to explain the structure of the Taconics. Some favor one over the other two or have adaptations or combinations of these for their own mapped areas. The three hypotheses are briefly described, to which the writer adds his own modified combination of the three which is particularly adaptable in northern Columbia County. All are illustrated with schematic structure sections (see Plate 4). Without benefit of a stereogram it is exceedingly difficult to illustrate the complex structure of the Taconics.

A. The Allochthone or Klippe Hypothesis is perhaps the most publicized. This presupposes that the Taconic Sequence was initially deposited far to the east and that emplacement of an allochthone of eugeosynclinal rocks was accomplished by westward low angle thrusting due to crustal shortening or gravity sliding. Subsequent erosion isolated the Taconic Sequence exposing contemporaneous miogeosynclinal (autochthonous) rocks on the east. Conceived by Ruedemann (1909) and elaborated by Keith (1912), this hypothesis has received the support of Marshall Kay, John Rodgers, Wallace Cady, J. Thompson,

R. Shumaker, L. Platt, D. Potter and G. Theokritoff. E-an Zen (1959, 1961) has altered this concept to say that the allochthone is a large flat-lying westward overturned anticline (nappe). Whereas Zen's theme is ingeniously suitable for the northern Taconics, no evidence for such a structure has been forthcoming by any worker in the southern Taconics.

B. The Bucher Hypothesis regards folding as the major means of deformation with the Taconic Sequence forming a tight anticlinorium and the migeosynclinal sequence forming adjacent tight synclinoria. Some faulting is admitted but large scale thrusting is denied. Shale to carbonate facies changes are viewed as more apparent than real but great weight is assigned important unconformities in explaining contrasting rock units. These unconformities are acknowledged as difficult to locate in deformed strata. Walter Bucher formulated this hypothesis based on the field work of his students, J. C. Craddock and J. Weaver, in the Kinderhook and Copake quadrangles respectively.

Misuse of certain paleontological data is obvious, especially in carbonate slices along faults and relative ages of certain rock units.

C. In situ Hypothesis - Adherents of the existence of rapid shale to carbonate facies changes (Christina Lockman, R. Balk, J. Elam) believe that the Taconic Sequence was deposited in place but that severe deformation compressed the rocks to such a degree that the original situation is greatly foreshortened. High angle reverse faulting is preferred over low angle thrusting and westward travel of an allochthone is rejected. This hypothesis fails to satisfactorily explain the mechanics of producing contemporaneous carbonate blocks along the major faults.

D. Field relations in Columbia County are satisfied by supposing peneisoclinal folding following Normanskill deposition with subsequent westward submarine gravity sliding of an allochthone into the Snake Hill sediments accompanied by spalling-off of heterogeneous rocks into the host sea. Uplift and erosion during the ensuing Silurian was succeeded, in the Middle and Late Devonian, by high angle reverse faulting thereby imbricating the Ordovician allochthone. Pre-Normanskill and post-Canadian folding and minor faulting is demonstrable. It is dubious whether there was any post-Early Cambrian and pre-Late Cambrian folding. The differing Lower Cambrian units beneath younger strata can be explained by admitting differential uplift and erosion or contemporaneity of differing Early Cambrian facies. Intricate inter-tonguing and time-transgressiveness of principal mapping units is evident but, as yet, inadequately worked out.

Lack of agreement on the manner of Taconic deformation remains as much a puzzle today as was the "Taconic System" over a century ago. Much tedious work remains for young energetic geologists with a keen mind and an observing eye.

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APPENDIX: SELECTED OUTCROPS, MARKED ON GEOLOGIC MAP

1. Troy quadrangle, along both sides of Red Mill Rd. (N. Y. 151), 1 mile west of N. Y. 40; slump blocks of Austin Glen Graywacke and Trenton Limestone in badly deformed Snake Hill Shale; Rysedorph Hill 0.2 mile to the northeast.

2. Berkshire Spur of Thruway (travelling east); no stopping permitted.

   (a) Kinderhook quadrangle, 0.5 mile east of U. S. 9; greenish-gray slaty argillite of Mettawee Formation.

   (b) Kinderhook quadrangle, few hundred feet west of crossing of N.Y. 203 at North Chatham and 0.3 mile further east; interbedded black shale, limestone and calcareous sandstone, beds nearly vertical, Lower Cambrian.

(c) Kinderhook quadrangle, 0.4 mile further east where Columbia County 32 passes beneath Thruway; grayish-green slaty argillite of Mettawee Formation.

(d) Kinderhook quadrangle, 1 mile further east, principally on west-bound lane; essentially vertical beds of interbedded black shale, limestone and calcareous sandstone, probably Lower Cambrian.

(e) Kinderhook quadrangle, 1.6 miles further east, principally on westbound lane; purple and green shales with interbedded thin red and green siltstones, Nassau Formation.

(f) Kinderhook quadrangle, 1.5 miles further east and 0.3 mile east of Old Chatham, also along town road paralleling Thruway; black slate, presumably Walloomsac, no fossils yet found, purple and green Nassau beneath, along town road. Nature of contact disputable.

(g) Kinderhook quadrangle, 3 miles further east and 1 mile east of East Chatham where N. Y. 295 passes over Thruway; Anticline in black slate (Walloomsac ?) on east-bound lane. Amos Eaton born at New Concord (Historic marker), 1.1 miles south of East Chatham.

(h) Pittsfield quadrangle, 3.8 miles further east, along both lanes; 1 mile of exposures of eastward dipping Stockbridge dolomites and dolomitic limestones, locally much deformed.

3. Pittsfield quadrangle, town road paralleling Thruway on the north, 1 mile west of B3 interchange; eastward dipping Stockbridge carbonates.

4. Pittsfield quadrangle, 1.2 miles east of Canaan at west end of Queechy Lake along N. Y. 295; fossiliferous Balmville Limestone on dolomite and underneath Austerlitz purple and green phyllite.

5. Pittsfield quadrangle, 0.2 mile southwest of Canaan along south side of B. & A. R.R. at junction with Columbia County 5; eastward dipping Austerlitz purple and green phyllite with interbedded thin green chloritic quartzite; black slate outcrops 500' to the west along the R. R.

6. Pittsfield quadrangle, 2.3 miles south of Canaan in tunnels of the B. & A. R.R.; Austerlitz purple and green phyllite thrust on Stockbridge carbonates, fossiliferous Balmville Limestone locally present.

7. Pittsfield quadrangle, 4 miles northeast of Austerlitz on west side of N. Y. 22; "Berkshire" black phyllite.

8. Kinderhook quadrangle, 2.4 miles west of Austerlitz and 5.3 miles east of Chatham along both sides of N. Y. 203; Rensselaer Graywacke with many quartz veins, some of which are feldspar-bearing.

9. Copake quadrangle, road-cut on west side of N.Y. 22 at Copake Falls; interbedded dolomite and shale with ripple marks (?) or flow structure (?) on dolomite, Pine Plains Formation.

10. Copake quadrangle, Taconic State Park, green Everett Schist on north side of N. Y. 344 at eastern edge of Park.

11. Copake quadrangle, 0.7 mile northeast of Copake at Tom Hill on west side of N. Y. 22; Copake Limestone and Balmville Limestone with distorted fossils due to flowage.

12. Copake quadrangle, along west side of Columbia County 7 at east end of Copake Lake; Balmville Limestone thrust on Walloomsac Slate.

13. Copake quadrangle, 5 miles east of Claverack and 1.5 miles south of present termination of Taconic Parkway at N. Y. 23; green argillite (Elizaville) and chloritic quartzite (Curtiss Mountain) along both sides of Parkway.

14. Catskill quadrangle, exposures on both sides of U. S. 9, 0.5 mile south of southern edge of Becraft Mountain; interbedded graptoliferous black shale and limestone (Germantown Fm.) and greenish-gray silty shale with Deepkill graptolites.

15. Catskill quadrangle, along west side of Columbia County 31 at Blue Hill, 1.5 miles southwest of southern edge of Becraft Mountain; red and green shale and much green chert, lower member of Normanskill Group.

16. Catskill quadrangle, 2.5 miles southwest of southern edge of Becraft Mountain along both sides of Columbia County 14; ferruginous quartzite overlying quartzose greenish-gray shale (Germantown Fm.)

17. Catskill quadrangle, 0.5 mile east of eastern terminus of Rip Van Winkle Bridge along south side of N. Y. 23; deformed Mt. Merino Shale of Normanskill Group.

18. Catskill quadrangle, 2.5 miles ESE of Germantown along Columbia County 8 and in Fisher's Quarry 500' to the northeast: interbedded black shale, limestone and limestone brecciola of Germantown Fm. overlying Mettawee green argillite.

19. Kinderhook quadrangle, in and along Kinderhook Creek at Stuyvesant Falls where Columbia County 25A passes over creek (type locality of Stuyvesant Falls Fm.); interbedded green silty shale and flow-cast green siltstones and chertified argillite underlying Mt. Merino shale of Normanskill Group.

20. Coxsackie quadrangle, roadcut along N. Y. 9J and cuts along railroad 1.9 miles south of Schodack Landing; grayish-green argillite (Mettawee) with fossiliferous limestone brecciola (Stuyvesant Conglomerate) near top, Mettawee overlain by laminated siltstones and interbedded black shales. Type locality of Schodack Formation.

21. Albany quadrangle, along the Normanskill at Kenwood between the Thruway and N. Y. 32, type locality of the Normanskill; gray and black shale with interbedded graywacke.

22. Cohoes quadrangle, along the Deep Kill 0.6 mile east of N. Y. 40 and 1 mile SSE of Melrose, type locality of the Deep Kill Formation; interbedded limestone and black shale in lower portion and greenish-gray shale in upper portion overlain by red shale of basal Normanskill. A reverse fault here repeats a portion of the section.

23. Cohoes quadrangle, in and along the Hoosic River where N. Y. 40 crosses it at Schaghticoke type locality of Schaghticoke Formation; interbedded green and black shale and thin limestones and siltstones, all badly deformed.

NOTES ON TRIP D. (TACONIC TRIP)

NOTES ON TRIP D

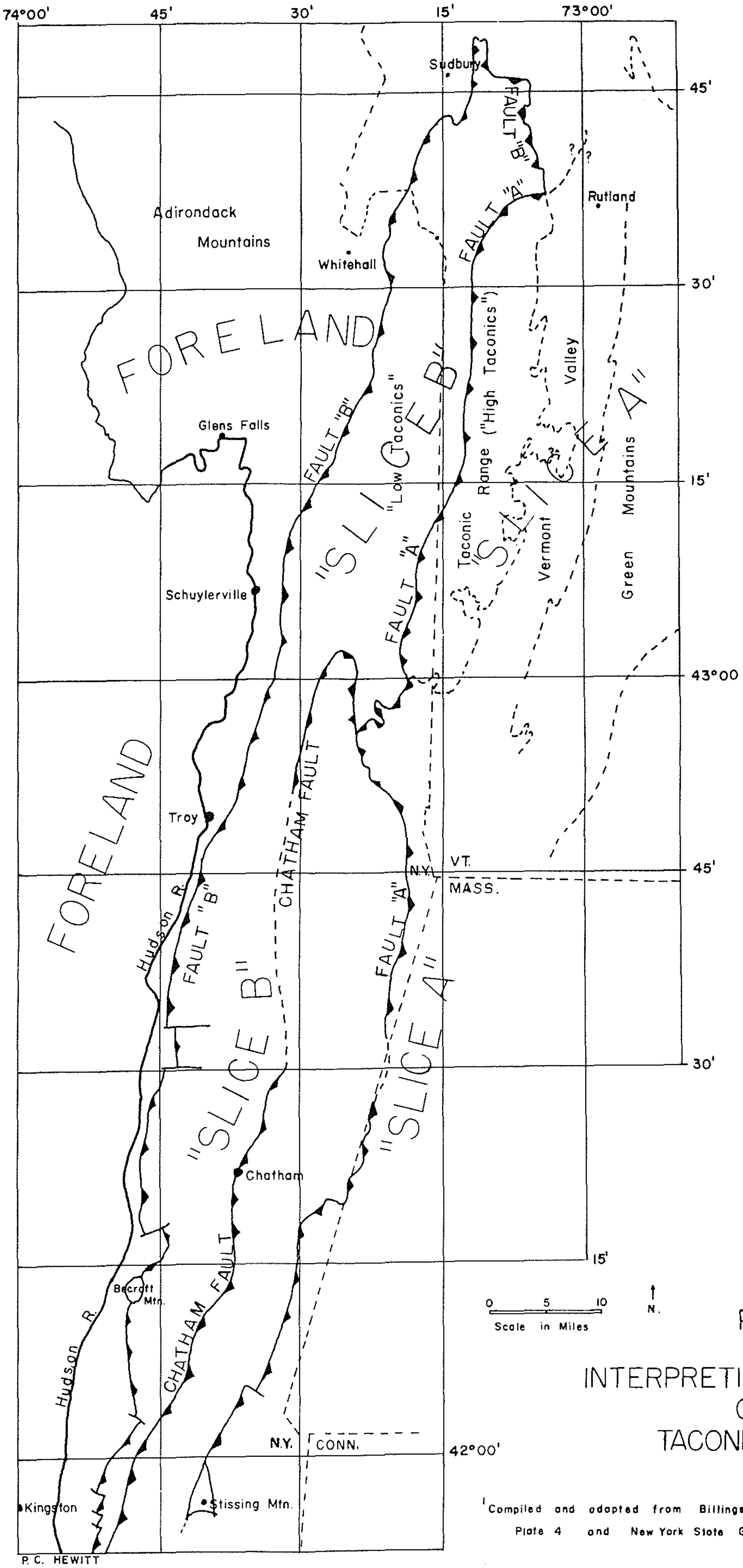

PLATE 5

INTERPRETIVE DIAGRAM OF TACONIC AREA[1]

[1]Compiled and adapted from Billings, Thompson and Rodgers, 1952; Plate 4 and New York State Geological Map (in press).