Bedrock Geology of the Glens Falls — Whitehall Region, New York

by DONALD W. FISHER

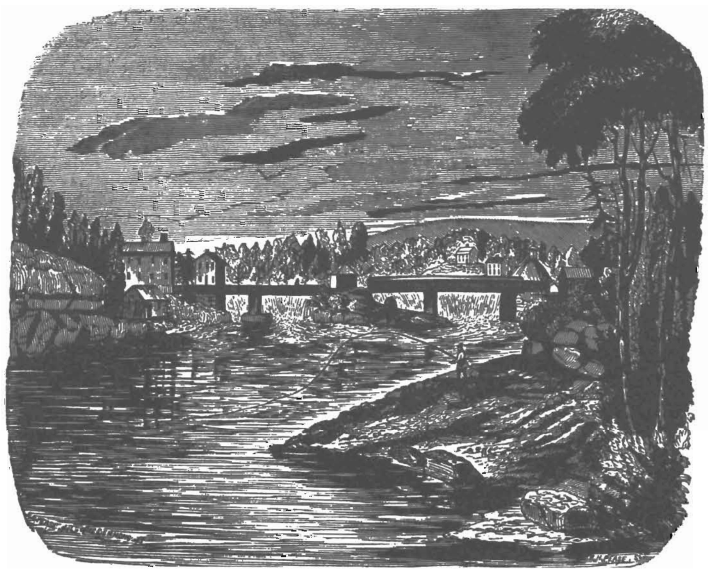

Figure 1. *Glens Falls, from a woodcut in "Geology of New York, Part 2, Comprising a Survey of the First Geological District" by Ebenezer Emmons, Sr. (1842)*

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Figure 2

PHANEROZOIC TIME SCALE

EON	ERA	PERIOD	EPOCH	MILLIONS OF YEARS	LIFE RECORD
PHANEROZOIC	CENOZOIC	Quaternary	Holocene		Man, mastodons, mammoths
			Pleistocene	½-2	
		Tertiary	Pliocene	7	Large carnivores
			Miocene	26	Abundant grazing mammals; Earliest known grasses
			Oligocene	37-38	Large running mammals
			Eocene	53-54	Many types of mammals
			Paleocene	65	Earliest placental mammals
	MESOZOIC	Cretaceous	Upper	100	Last of the dinosaurs; Earliest flowering plants; Climax of dinosaurs and ammonites; Great decline of brachiopods; Great development of bony fishes
			Lower	136	
		Jurassic	Upper	162	Earliest birds and mammals; Abundant dinosaurs and ammonites
			Middle	172	
			Lower	190-195	
		Triassic	Upper	205	Earliest dinosaurs. Abundant cycads and conifers
			Middle	215	
			Lower	225	
	PALEOZOIC	Permain	Upper	240	Extinction of many marine animals, including trilobites; Little change in terrestrial animals
			Lower	280	
		Carboniferous	Pennsylvanian	310*	Earliest insects; Earliest reptiles. Great coal-forming forests
			Mississippian	345	Abundant sharks and amphibians; Large, numerous scale trees and seed ferns
		Devonian	Upper	359	Earliest amphibians and ammonites; Extinction of armored fishes, other fishes abundant
			Middle	370	
			Lower	395	
		Silurian	Upper		Earliest land plants and animals (scorpions); Peak development of eurypterids; Earliest fishes in New York
			Lower	430-440	Great diversity of echinoderms and ostracodes
		Ordovician	Upper	445	Earliest fishes; Invertebrates dominant-coelenterates, mollusks and arthropods become abundant: echinoderms expand in numbers and kinds; earliest known coral reef in early Middle Ordovician time; Graptolites very abundant
			Middle		
			Lower	500	
		Cambrian	Upper	515	Algal reefs well developed in New York
			? Middle	540	Earliest abundant record of marine life though types are limited; Trilobites exceed all other life forms in numbers and kind
			Lower	570	
CRYPTOZOIC EON				1100	Fossils extremely rare, primitive aquatic plants
ORIGIN OF THE EARTH				4500	

RECORD IN NEW YORK — FOSSIL: Plants, Invertebrates, Vertebrates — ROCK: conglomerate, sandstone, shale, limestone, dolostone, gneiss

DATES (except*) FROM: Quarterly Jour. Geol. Soc. London, v. 120, p. 260-262 (1964)

Gray horizontal bands denote time the rocks were deposited in the Glens Falls-Whitehall region

NEW YORK STATE GEOLOGICAL SURVEY, STATE EDUCATION DEPARTMENT
Compilation, Donald Fisher Graphics, John Skiba 1/81

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Figure 3. *Glens Falls, on the Hudson River, looking upstream from the bridge carrying U.S. 9; thin-bedded Glens Falls Limestone above and massive Isle la Motte Limestone below.*

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FOREWORD

The geology of the Glens Falls-Whitehall region is important to our understanding of not only the geologic history of the northern Appalachians but also the structural and stratigraphic setting of any petroleum resources that might occur in the area. Donald Fisher spent many years studying the stratigraphy and structure of the autochthonous lower Paleozoic rocks of Washington County. His work is presented here in colored maps, cross sections, and diagrams. Fisher did not map in detail the allochthonous rocks east of the Taconic frontal fault, also called the Giddings Brook Fault, which extends north-south along the eastern side of the region, or the Precambrian metasedimentary rocks exposed northwest of Fort Ann and Whitehall. The composition and structure of the autochthonous rocks of the area cannot be interpreted without comparison with these same features in the allochthonous rocks to the east of the Giddings Brook Fault. Therefore, Fisher graciously consented to the addition of the work of many others to his maps. Mapping styles, interpretations of structure, and reconstructions of geologic history differ among workers, however, and although Fisher has consented to have the additional data presented herein, he does not necessarily agree with the portrayal of the geology of the Taconic allochthonous rocks.

William S. F. Kidd of the State University of New York at Albany, contributed to and compiled the work of his students in the area east of the Giddings Brook Fault. P. R. Whitney and Y. W. Isachsen, and I take responsibility for the reconnaissance interpretations of the Precambrian rocks immediately west of Whitehall. Index maps give the name of the field worker responsible for the primary interpretation of each subarea.

If this departure from the usual manner of presentation of geologic mapping makes this report more stimulating and useful, the effort will be worthwhile regardless of which worker in the future is considered to have made the more correct interpretations.

ROBERT H. FAKUNDINY
State Geologist

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Figure 4. *Typical Taconic-type folding (westwardly overturned isoclinal folds) in ribbon limestones and interbedded black shales; Upper Hatch Hill formation. North side of U.S. 4, 4.5 miles of northeast of Whitehall, N.Y. and 3 miles southwest of Fairhaven, Vt.*

Bedrock Geology of the Glens Falls — Whitehall Region, New York[1]

by Donald W. Fisher[2]

ABSTRACT

The area covered in this report includes portions of Saratoga, Warren, and Washington Counties, New York and extends from within the Adirondack Mountains, slightly west of Lake George, through Whitehall crossing the upper (southern) Champlain Valley to the Vermont State Line within the Taconic Mountains. Also included is a segment of the Hudson River Valley, centered around Glens Falls, Hudson Falls, and Fort Edward. Topographically and geologically, the region may be conveniently divided into three terranes: Adirondack Uplands, Hudson-Champlain Lowlands, Taconic Uplands. The mapped area encompasses about 525 square miles.

The rocks range in age from over 1,100 million years (Medial Proterozoic) to about 440 million years (Medial Ordovician) but some local diabase dikes may be as young as 100 million years (Early Cretaceous). Proterozoic rocks may be separated into 3 suites: 1) an older folded and metamorphosed "basement" of charnockitic gneiss (Pharaoh Mtn. Formation) of uncertain origin, 2) a younger Lake George Group of metasedimentary rocks (Eagle Lake, Paradox Lake, Treadway Mountain, Springhill Pond, Thunderbolt Mountain Formations); further subdivision into Alling's mapped units has been successful, and 3) igneous (plutonic) intrusions (anorthosite, Barton Mountain Leucogranite, Prospect Mountain hornblende granite, and olivine gabbro). A 1,100 million year old mountain-building episode, termed the Grenville Orogeny, was followed by a less intensive injection of pegmatite dikes about 930 million years ago, which are unfolded and unmetamorphosed.

Paleozoic rocks include: (1) Beekmantown Group, consisting of 515-500 million year old Late Cambrian (Postdam Sandstone, Ticonderoga Dolostone, lower Whitehall Formation) and 500-470 million year old Early Ordovician (upper Whitehall Formation, Great Meadows Formation, Fort Ann, and Fort Cassin Formations); (2) Black River and Trenton Groups, composed of 455 million year old Medial Ordovician shelf carbonates (Isle la Motte and Glens Falls Limestones); and (3) basin-deposited Medial Ordovician Snake Hill Shale with its included unique and exotic Forbes Hill Conglomerate. Early Cambrian through Medial Ordovician slope-rise-basin strata are pelites and graywackes, and include the Nassau, Brown's Pond, Middle Granville (*new*), Hatch Hill, Poultney, Indian River, Mt. Merino, and Austin Glen (=Pawlet) Formations. These make up the Taconic Sequence of westwardly thrust-faulted rocks.

Many faults criss-cross the region. Eight separate fault systems have been identified. Chief among these are a north-south high-angle fault system, which is responsible for the tilt-block topography east of Lake George, and a low-angle gravity-slide fault system which caused Cambrian-Ordovician slope-rise-basin strata to move westward over shelf deposits during the Taconic Orogeny. At least three periods of folding have been recognized in both the Proterozoic rocks of the Adirondack Uplands and the Paleozoic rocks of the Taconic Uplands, though their times of formation are separated by over 600 million years. Both transported (allochthonous) and *in situ* (autochthonous) Paleozoic rocks exhibit cleavage, suggesting that this overprint was post-thrusting.

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[1] Submitted for publication, September 1982.

[2] *Former State Paleontologist*, N.Y State Geological Survey, N.Y. State Museum, Cultural Education Center, Albany, New York 12230.

Plate 1, the colored geologic map (scale 1:48,000), is a mosaic of nine entire 1:24,000 quadrangles. It depicts the geographic distribution of 51 mapping units, 19 of which are classed as Proterozoic, 30 as Paleozoic, 1 as Mesozoic?, and 1 as Cenozoic. The several types of Cenozoic (Pleistocene & Holocene) sediments, which partly conceal the bedrock, are grouped together under a single mapping unit (Qs); they have been delineated in detail by Connally (1973, N.Y. State Museum, Map & Chart Series 23.) Also shown on Plate 1 are faults (with movement, if known) dip and strike data, fossil control sites, and outcrops, including special ones recommended for class study.

Plate 2, seven structure cross sections, presents the third dimension or vertical attitude of the rocks across selected traverse lines. Major faults are located.

Plate 3, a schematic sequence of eight stratigraphic profiles and seven paleogeographic maps, depicts situations from Medial Proterozoic to Late Ordovician ages. For each interval of time there is a restored sedimentary realm profile showing the strata which accumulated during that specified interval and a corresponding map illustrating depositional sites and supposed land areas.

There are brief sections on previous geologic work, geologic history, paleoenvironments, structures, selected rock exposures, geologic problems remaining, economic resources, and a selected bibliography. Many photographs and line-drawings complement this geological study of an area that displays the closest approach of Cambrian-Ordovician pelites of the Taconics to the metamorphosed Proterozoic rocks of the Adirondacks.

ACKNOWLEDGMENTS

Robert H. Fickies, N.Y. State Geological Survey environmental geologist, reviewed and made helpful suggestions on the portion of the map legend concerning "Environmental and Economic Characteristics" of the rocks. Robert H. Fakundiny and Lawrence V. Rickard of the N.Y. State Geological Survey, reviewed the text. John B. Skiba, Senior Cartographer with the Survey, made the understanding of the regional geology easier by utilizing his considerable talents and expertise in preparing lucid line drawings and artwork. All photographs were taken by Donald W. Fisher.

Thanks and appreciation are extended to the numerous property owners, the N.Y. State Police, and those in charge of State Parks, State Campsites and the Prospect Mountain Memorial Highway, for their willing cooperation in allowing study and photography of rocks on lands under their jurisdiction.

Linda L. Roberts, assistant to William M. White, President of The Saratoga Springs Company, kindly permitted use of the log data of the Saratoga Vichy Spring core (Figure 42).

PURPOSE OF STUDY

My introduction to the geology of this area came in 1949, in company with Rousseau H. Flower (then Assistant State Paleontologist) who was engaged in collecting nautiloid cephalopods from the Beekmantown Group of the Fort Ann region. I was struck both by the similarity of some, and by the dissimilarity of others of these Cambrian-Ordovician carbonate rocks and fossils to those in the Mohawk Valley and Saratoga Springs regions where I had been intensively mapping and studying the Early Ordovician Tribes Hill Formation and related strata. During compilation of the 1960 State Geologic Map, in the late 1950's, my attention was redirected to the region owing to a dearth of information on both the distribution of bedrock units and the occurrence of major faults in the Glens Falls, Fort Ann, and Whitehall 15-minute quadrangles. Accordingly, time was spent in reconnaissance mapping in order to partially remedy these deficiencies. Improvement in our knowledge of the bedrock geology was sought during compilation (in 1968 and 1969) of the 1970 State Geologic Map and, therefore, additional mapping was conducted in the region at that time. Since then, mapping has been conducted intermittently until the spring of 1981. Over the years, knotty unanswered questions relating to the stratigraphy, sedimentology, paleontology, correlation, and structure of the relatively undeformed foreland rocks prompted a full-scale effort to complete detailed bedrock mapping in the region. The present study has been particularly timely because interest currently is focused on this part of eastern New York and adjacent Vermont as a possible producer of natural gas. Corporations desiring to test this potential, via deep drilling, are, of necessity, exceedingly interested in learning more about the makeup and attitudes of the rocks and the positions of faults and folds in this previously unmapped area.

Many, but not all, objectives were attained. Those attained include:

(1) Paleozoic bedrock units of the Lake George, Glens Falls, Hudson Falls, Putnam Mountain, Fort Ann, Whitehall, and part of the Thorn Hill, Granville, and Hartford 1:24,000 quadrangles were mapped in detail;

(2) Fault systems were identified and major faults were plotted where stratigraphic separation or other fault criteria was obvious;

(3) The Cambrian-Ordovician Beekmantown Group was subdivided successfully into 16 valid mapping units distributed among 6 formations;

(4) More precise correlations of the Beekmantown Group with strata in other areas was accomplished, based upon nautiloid cephalopods, gastropods, trilobites and specific lithologic characters;

(5) Sedimentologic studies were completed on some Beekmantown Formations, namely the Whitehall, Great Meadows and Fort Ann.

Serendipitous discoveries were a pleasant bonus to this work. Some of the more significant items are:

(1) chevron-folding in the Mohawkian limestones west of the main Taconic thrust (Emmons' or Logan's Line) and the presence of a low-angle thrust (Comstock) of Beekmantown carbonates over Beekmantown carbonates attendant to this folding.

(2) surprisingly greater concentration of Medial Ordovician mélange or wildflysch between the foreland shelf carbonates and Emmons' Line,

(3) presence of several erosional surfaces and sedimentary breaks within the Beekmantown Group,

(4) identification of the *Paraplethopeltis* trilobite zone within the Smith Basin (formerly Fort Ann) Limestone,

(5) discovery of *Isochilina*-like ostracodes low in the Fort Cassin Formation,

(6) realization that H.L. Alling's stratigraphy of the "Grenville" rocks (1918, 1925) was applicable to the Precambrian rocks of this region.

The results of these many years of field and laboratory labor are portrayed on Plate 1 (Map of Bedrock Geology), Plate 2 (Structure Cross-Sections), and Plate 3 (Schematic Stratigraphic Profiles and Paleogeographic Maps) and in the text and illustrations which follow.

HISTORY OF PREVIOUS WORK

The earliest definitive exposé of the regional bedrock geology was by William W. Mather (1843) in his *Geology of New York, Part 1, comprising the geology of the First Geological District.* Washington County occupied the northernmost segment of the First Geological District, which extended south to New York City and west to Schoharie County. This District was one of four of the New York State Geological and Natural History Survey of 1836 to 1841. The adjacent "Second District" encompassed northern New York, included Warren County, and the report of this district, by the famous Ebenezer Emmons (1842), utilized stratigraphic terminology that extended into neighboring Washington County. It was Emmons who promoted the "Taconic System," which he believed to be older than the Potsdam Sandstone, the basal unit of the "New York System." See Fisher (1981) for an in-depth-discussion of the early years of the New York State Geological Survey and its impact on later work and geologic thought.

In the late 1800's, Ezra Brainerd and Henry M. Seely (President and Professor of Geology, Middlebury College, Vermont, respectively) measured and described sections of the "Calciferous Sandrock" in the Champlain Valley, outside of the mapped area. Their careful descriptions, particularly in the Shoreham, Vermont area, provided the original basis for subdividing the thick, seemingly monotonous sequence of quartz-carbonate rocks later known as the Beekmantown Group.

Although fossils had been known from the region, Charles D. Walcott (1879, 1912) was the first serious investigator of them within the area covered by this report. Walcott was a protégé of the famous James Hall and a student of Hall's apprentice school for paleontologists in Albany, N.Y. Walcott later became Director of the U.S. Geological Survey and of the Smithsonian Institution.

Kemp and Newland (1899) conducted, in 1897, a geological reconnaissance of Warren and Washington Counties which resulted in generalized bedrock maps of the townships on a scale of 2 miles/inch. These were used in compiling the 1901 State Geologic Map.

T. Nelson Dale was one of the most astute field geologists to work in the Taconic Mountains. His classic paper (1899), *The Slate Belt of Eastern New York and Western Vermont,* covered most of Washington County, and included descriptions of rock types, fossil localities, and commercial slate sites. Dale was a proponent of folding but not faulting and his geologic map (good for that day) is testimony to his structural philosophy for it shows very few faults. One of Dale's chief and lasting contributions was the establishment of the sequence of rock formations — though he abstained from assigning formal geographic names to them.

	Dale's "Northern" Sequence	Modern Name
A	Olive Grit or Graywacke	Bomoseen Member of Nassau formation
B	Cambrian roofing slates	Mettawee Member of Nassau Formation
C	Black Patch Grit	"Eddy Hill Grit," West Castleton Formation, in lowest Hatch Hill of Kidd
D	Cambrian black shale	Schodack Formation of Ruedemann (1914); West Castleton Formation of Zen (1959), Hatch Hill of Kidd
E	Ferruginous quartzite & sandstone	Eagle Bridge Quartzite, Hatch Hill Formation
F	Calciferous	Beekmantown Group
G	Hudson shales	Mixture of Poultney, Mt. Merino, and Snake Hill Formations
Hw	Hudson white beds	Upper Poultney, Mt. Merino cherts
Hq	Hudson thin quartzite	Poultney?, Mt. Merino cherts
Irs	Hudson red green slate	Indian River Formation
Ig	Hudson grits	Austin Glen Graywacke

Ruedemann (in Cushing and Ruedemann, 1914, p. 69-70) applied formal geographic names to Dale's "southern" sequence: Nassau, for Divisions A to E, Bomoseen for the olive grit, Mettawee for the Cambrian roofing slate, Eddy Hill for the Black Patch grit, Schodack shales and limestones for the Cambrian black shale, Diamond Rock Quartzite for Division G, Troy shales for Division H, and Zion Hill Quartzite for the ferruginous quartzite. The name Eddy Hill has been abandoned as it is very thin and not mappable. Zen chose to use Keith's (1932) name Bull for Nassau, and proposed (Zen, 1959) West Castleton for Schodack and

Mudd Pond for Diamond Rock. Troy is a name for many mappable units of differing ages, ranging from Early Cambrian to Medial Ordovician and has no apparent usefulness. Ruedemann proposed the names Schaghticoke (1903) and Mt. Merino and Austin Glen (1942). To complete the register of Taconic names for Washington County, Keith (1932) proposed Poultney and Theokritoff (1959) proposed Hatch Hill.

Harold L. Alling (1918, 1925) applied the principles of sedimentology and stratigraphy to the Precambrian metamorphic rocks during his studies of Adirondack graphite deposits. His discoveries in Warren and Essex Counties demonstrated that these highly deformed and multi-penetrated rocks have a recognizable stratigraphy. His successors in Proterozoic mapping owe him a great indebtedness for his perceptive observations which, interestingly, were unheeded by many Precambrian workers.

John Rodgers, trained at the Albany Academy and benefitting from "after-school" tutelage from Drs. Ruedemann, Goldring, and Hartnagel at the then nearby New York State Museum, chose the southern Champlain Valley as the subject area for his master's thesis (Cornell, published in 1937.) He named the Whitehall Formation and designated Skene Mountain as the type locality. Utilizing Brainerd and Seely's "alphabet" divisions, he mapped Beekmantown rocks within several 15-minute quadrangles in New York and Vermont, extending from Port Henry in the north to Whitehall in the south. None of these maps were published but the data have served subsequent field workers and compilers of the State Geological Maps of New York (Fisher, Isachsen, Rickard, 1970) and Vermont (Doll, and others, 1961.)

Four decades ago, the New York State Museum issued an article by David H. Newland and Henry Vaughan (1942) covering, in a generalized fashion, the geology of the Lake George region. This included a preliminary colored geologic map (scale 1:62,500) emphasizing the Precambrian rocks, and was an attempt to furnish new geologic information and to fulfill the needs of the nongeologist. Twenty field excursions were detailed. Strangely, Alling's earlier stratigraphic work was not utilized and outcrops were not shown on the geologic maps.

That same year Robert R. Wheeler (1942) summarized the data for his doctoral thesis at Harvard in a short article on the southeast Adirondack border region that leaves more undecided than decided. Several new stratigraphic names were proposed, all without designation of type localities and with little or no lithological descriptions nor lists of faunal content. Some of his ideas, however, have provoked questions concerning the complex facies relations that exist within the Beekmantown Group. His extension of the name Tribes Hill from the Mohawk Valley into the Whitehall area was unfortunate.

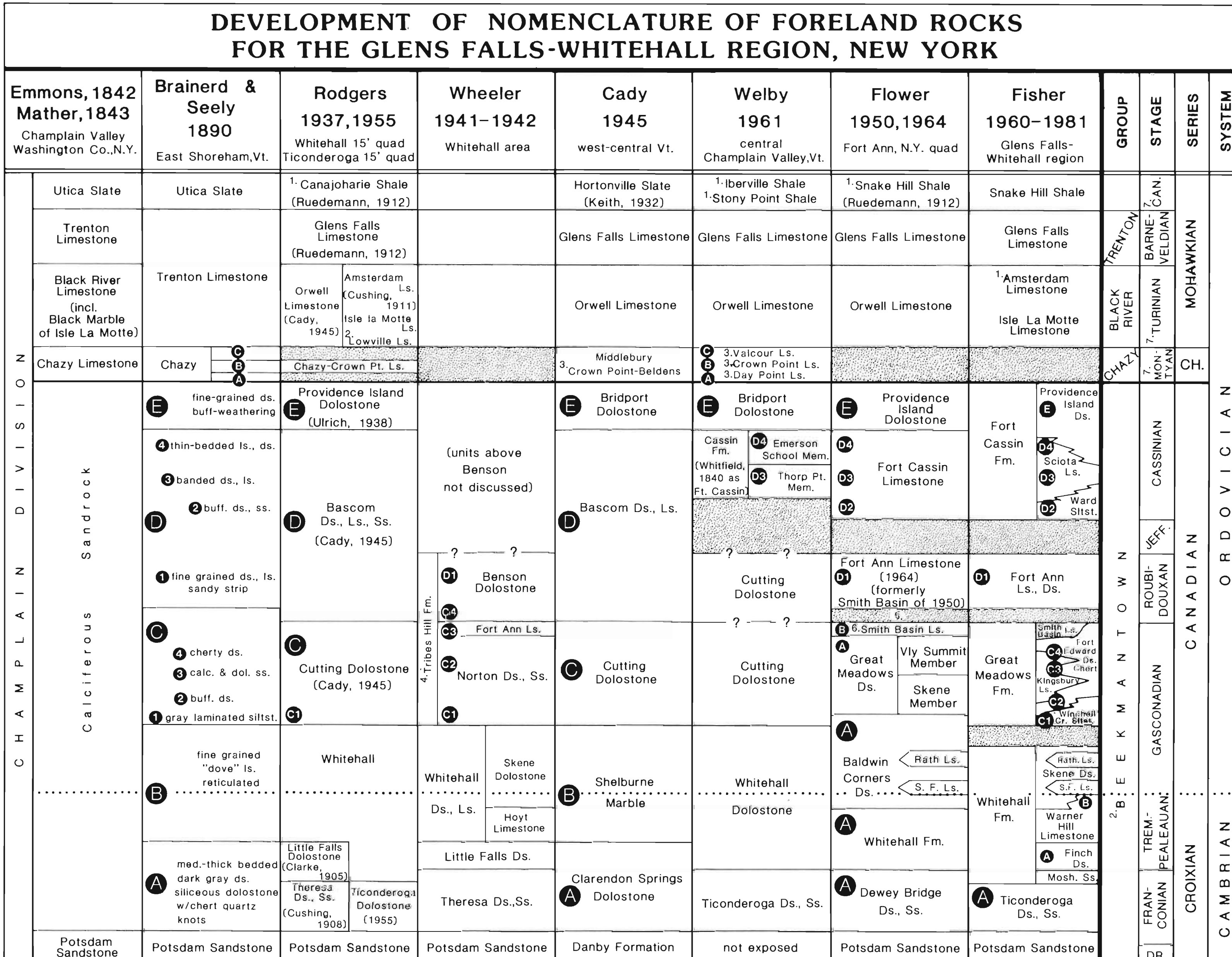
McConnell (1965), Platt (1960), and Theokritoff (1964) mapped the Bolton Landing, Cossayuna, and eastern Thorn Hill-northern Granville 7½-minute quadrangles on the north, south, and east, respectively. Their mapping has acted as perimeter control for my mapped area.

Rousseau H. Flower (1964a, 1964b, 1968a, 1968b) spent several years collecting and describing fossils, chiefly nautiloid cephalopods, from the Fort Ann region. A workable biostratigraphy of nautiloid zones was established. His lithostratigraphy was not as successful. He proposed a number of new stratigraphic names (most of which were unnecessary) for poorly defined rock units. In addition, transfer of some stratigraphic names (Fort Ann vs. Smith Basin) has created confusion. Because of the absence of any culture, his geologic map (1964b) of the Fort Ann region is virtually unusable.

Unpublished Yale Ph.D. theses by Richard Berry (1960) and F. Alan Hills (1965), on which the Precambrian rocks of the Whitehall and Lake George regions, respectively, were mapped, form the basis for the distribution of Proterozoic rocks depicted on my colored map (Plate 1.) Their data have been recast, with modern stratigraphic appraisal by Richard Wiener, Yngvar Isachsen, and myself. In a few instances their mapping has been modified and supplemented by examination of outcrops not available to them, such as the Adirondack Northway (I-87), the Prospect Mountain Memorial Highway, and relocated U.S. 4 and N.Y. 22.

Following the refinement of the stratigraphic sequence both in the northern (Fisher, 1968) and in the southern (Fisher, 1969) Champlain Valley, graduate students have conducted intensive sedimentological research at Rensselaer Polytechnic Institute during the past decade. This has resulted in doctoral theses by Mazzullo (1974) on the Great Meadows and Fort Ann Formations, by Keith (1974) on the shelf-edge and slope-carbonates and -shales, and by Rubin (1975) on the Whitehall Formation. Simultaneously, Taylor and Halley (1974), as an outgrowth of Halley's earlier paleoenvironmental study (1971) of the stromatolites in the Warner Hill Limestone Member of the Whitehall Formation, demonstrated that the Early Ordovician *Missisquoia* Zone occurred above the Late Cambrian *Saukia* Zone in the Whitehall Formation, northeast of Whitehall. Eleven trilobite species were described. Their work corroborated my earlier (Fisher, 1969) announcement that the Cambrian-Ordovician boundary lay within the Whitehall Formation, above the Warner Hill Limestone. Cooperatively and independently,

Figure 5



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Compilation Donald W. Fisher
Graphics John B. Skiba 8/81

1. name proposed by other (usually earlier) worker
2. Clarke & Schuchert, 1899
3. Cushing, 1905
4. Ulrich & Cushing, 1910
5. considered C to be absent
6. formerly Fort Ann
7. Fisher, 1977

hiatus, rock absent

Rath. Rathbunville School
S.F. Steve's Farm
Mosh. Mosherville

CAN. CANAJOHARIAN
CH. CHAMPLAINIAN
JEFF. JEFFERSONIAN
DR. DRESBACHIAN

Figure 5. Development of Nomenclature of Foreland Rocks for the Glens Falls-Whitehall Region, New York.

Fisher and Mazzullo (1976) presented detailed stratigraphic and sedimentologic analyses of the Lower Ordovician Great Meadows Formation.

In an unpublished report, not generally available, John H. Johnsen and Charles W. Welby (1966) mapped carbonates in the Fort Ann 7 ½-minute quadrangle in an effort to identify those units which gave promise of economic use.

In a comprehensive correlation of Ordovician, Cambrian, and Hadrynian rocks in New York State, I (Fisher, 1977) related the stratigraphic units of the Whitehall and Glens Falls 15-minute quadrangles to their correlatives elsewhere within the State. A roster of pre-Silurian stratigraphic units was presented with recommendations for continued usage or abandonment. Figure 5 summarizes the history of development of stratigraphic nomenclature within the area under discussion.

SETTING

For over three centuries, the Lake George-Glens Falls-Whitehall region has functioned as a population movement corridor, earlier for migrating Indians, French trappers, missionaries, invading and retreating armies, and more recently, as a tourist thoroughfare and vacation spot. It has been the site of confrontations between American Indians and European immigrants, between French and British armies, and between British Loyalists and American Patriots. The Ticonderoga-Saratoga link via either Lake George or Whitehall-Fort Ann-Fort Edward-Schuylerville was a strategic one in the Montreal-New York chain during the American Revolution. Success or failure to control this link was dependent, to a major degree, on the advantages or disadvantages of local topography. The positioning and occupation of promontory hills was all important in the maintenance of unobstructed traffic flow through the lowlands and waterways. Skene Mountain, Tub Mountain, Battle Hill, Tongue Mountain, French Mountain, Pilot Knob, and Prospect Mountain were elevated points of vantage whereas South Bay, Wood Creek, Lake George, and the Hudson River were the principal waterways. The lowland avenues hosted famous overland expeditions. One was General Henry Knox's successful trek from Boston, Massachusetts with an artillery contingent for the defense of Fort Ticonderoga. Another, as part of a three-pronged attempt to capture Albany, was the ill-fated southward invasion by General John Burgoyne's British Army — to be stopped by the American Army directed by General Horatio Gates at the Battle of Saratoga.

A British Army officer, Colonel Philip Skene, founded the town of Whitehall — earlier termed Skenesborough. Overlooking the village on the northeast is Skene Mountain (Figure 6), the site of British and American troop battles and Indian encampments. In the mountain's shadow, the American Navy spent its infancy. It was here that Skene's schooners were constructed on Wood Creek. But the vessels were captured by Ethan Allen and his "Green Mountain Boys" and became the nucleus for the first American fleet, built by Benedict Arnold. The fleet secretly moved through South Bay and then sailed north on Lake Champlain, where it defeated the British in the Battle of Valcour Island.

Figure 6. *Looking south from Skene Mountain; Whitehall in right foreground (adjacent to Champlain Canal); Tub Mountain and Paleozoic carbonate hills in left background; West Mountain and dipslope of Proterozoic gneisses in right background.*

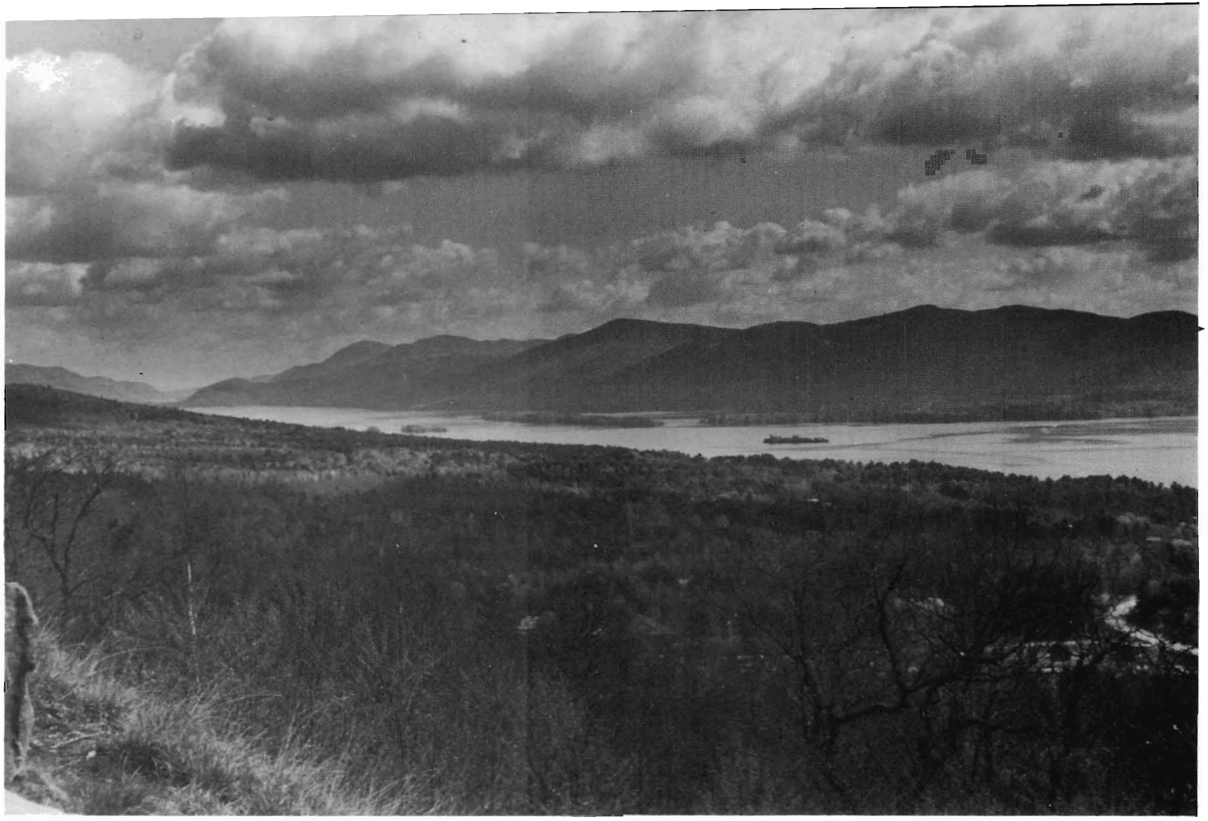
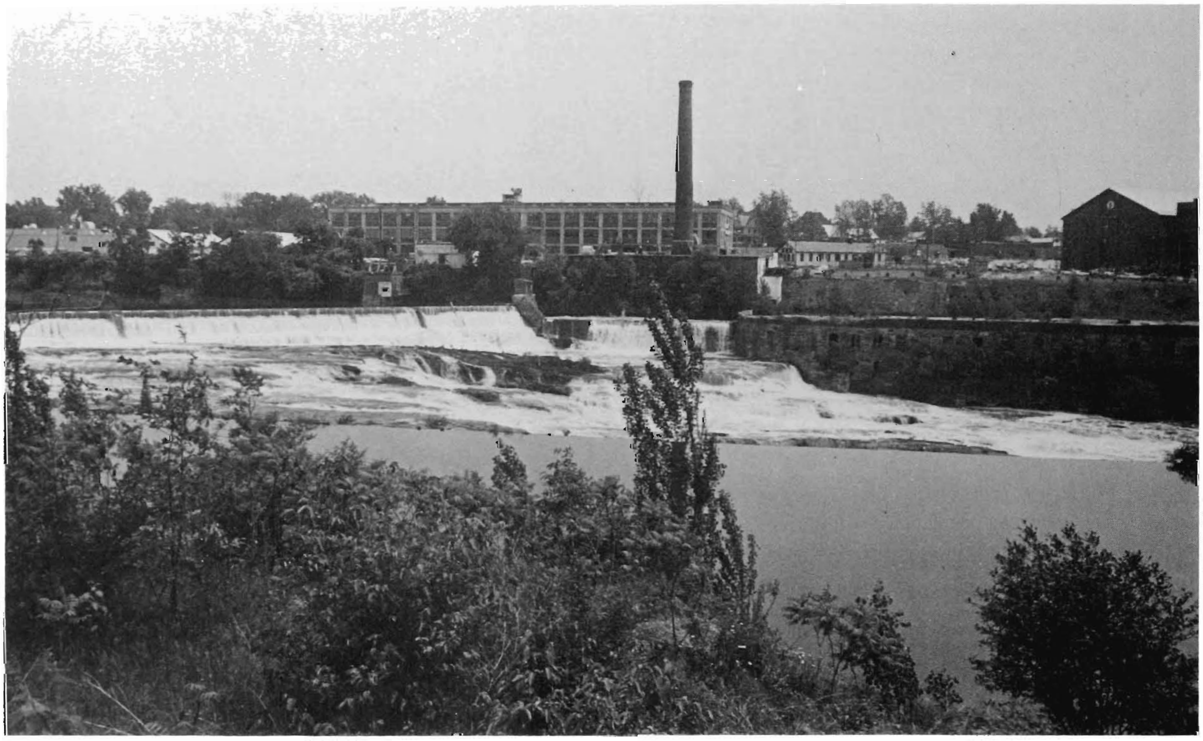


Figure 7. *Lake George, looking northeast toward Pilot Knob ridge from overlook on Prospect Mountain Memorial Highway. Long Island in center of picture with Assembly Point to its right; the small island this side of Assembly Point is Diamond Island.*

Figure 8. *Bakers Falls, over lowermost calcareous mudstone of Snake Hill formation, on Hudson River; village of Hudson Falls on far bank.*



Only the southern segment of Lake George, one of the most picturesque lakes in the State, and the site of historic Fort George occurs within the mapped area. The lake, dotted by a few islands of sedimentary rocks, occupies the downdropped (Figure 7) rift or graben floor. The valley is flanked by steep-sided metamorphic rock walls which are the fault traces of large north-south trending normal faults. Auxilliary faults splay from these and a north-northeast trending set of tear faults dissect the valley floor.

The Hudson River enters the area through the water gap north of Palmerton Mountain in the southwestern corner of the map. From here the river courses eastward, meandering across a sediment plain of very low relief until reaching the falls with a drop of about 50′ over the Black River and Trenton limestones at Glens Falls, just west of the bridge accommodating U.S. Route 9. Eastward from here the bed of the river is on a rock floor to Bakers Falls (Figure 8) with a drop of 65′ at the village of Hudson Falls, where the river cascades over the Snake Hill Shale. Downstream, at Fort Edward, the river begins its southerly directed flow to the Atlantic Ocean — about 190 miles beyond.

Aside from the Hudson River, the chief streams of the region are the Poultney River (into which the Hubbardton River and Coggman Creek enter from Vermont), Mettawee River (which enters into East Bay), Big Creek (enters into the Champlain Canal at Smiths Basin), Halfway Creek, northwest of Fort Ann (Figure 9) and Wood Creek, which has its origin on the Hartford Quadrangle east of Fort Edward and flows north, paralleling the Champlain Canal, reaching East Bay at Whitehall. The natural drainage divide between the Champlain and Hudson basins cuts diagonally across the Hudson Falls Quadrangle from northwest to southeast and, specifically, lies on the low ridges where Wood Creek flows north into Lake Champlain and Dead Creek flows south into the Hudson River.

The 25-mile long non-Hudson River portion of the Champlain Canal extends from its juncture with the Hudson River south of Fort Edward to East Bay at the north edge of Whitehall. Along this route are five locks: Lock 7, 0.8 mile south of Fort Edward near juncture with Hudson River; Lock 8, 1.5 miles northeast of Fort Edward; Lock 9, 0.5 mile south of Smiths Basin; (there is no lock 10); Lock 11, 0.5 mile north of Comstock; Lock 12, at Whitehall (Figure 10.) Between

Figure 9. *Kane Falls, 1 mile northwest of Fort Ann, on Halfway Creek; face of falls is a faultline scarp.*

Figure 10. *Lock 12 on Champlain Canal at Whitehall; Skene Mountain on left.*

Figure 11. *Abandoned lock on former Champlain Canal; east edge of village of Fort Ann. Dimension stone constructed of various Beekmantown carbonates and Isle la Motte Limestone.*

the Hudson River and Whitehall there is a drop in elevation of 35 feet, from 130 feet above Lock 7 to 95 feet below Lock 12; canal level is maintained at 135 to 140 feet between Locks 8 and 9. The original Champlain Canal, with preserved locks (Figure 11) and retaining walls, parallels and is adjacent to much of the present canal channel.

Aside from Lake George and South Bay (of Lake Champlain), the chief lakes and ponds of the region are: Glen Lake, Butler Pond, Hadlock Pond, Lake Nebo, Copeland Pond, Pine Lake, and Lakes Pond. Of additional interest is the 4-mile long Tamarack Swamp, which parallels and lies next to the west-facing Taconic Range between North Argyle and South Hartford.

Within the mapped region, the lowest elevation is at 95 feet above sea level where Lake Champlain leaves the map on the north; where the Hudson River leaves the map on the south, the elevation is slightly less than 120 feet above mean sea level. The highest elevation is at Pilot Knob (2,163 feet above sea level) in the north-western quadrant of the Putnam Mountain Quadrangle in western Washington County; Prospect Mountain (2,020 feet above sea level), 1.5 miles west of Lake George Village is the highest peak in the mapped portion of Warren County. Maximum relief, therefore is about 2,070 feet.

Physiographically, the region may be divided into three distinct terranes (Figure 12): (1) **Adirondack Uplands,** (2) **Hudson-Champlain Lowlands,** (3) **Taconic Uplands.**

(1) **Adirondack Uplands** — rugged, forested hills with no particular trend, ranging, for the most part, between 500′ and 1,800′ elevation; moderate to high relief. Occasional peaks are higher: Pilot Knob (2,163′); Prospect Mountain (2,020′); Sugarloaf Mountain (1,990′) 6 miles north of Whitehall; Vanderberg Mountain (1,920′) 5 miles southwest of Whitehall. The Uplands southern margin east of Lake George appears as a series of eastwardly dipping, step-like wedges or blocks with rather abrupt western margins; relatively extensive bedrock exposures; exclusively intensely deformed high-grade metamorphic rocks of Proterozoic age.

(2) **Hudson-Champlain Lowlands** — open, sparsely wooded, flatlands with very low to low relief having elevations generally less than 400′ but occasional ridges reach 500′; extensive farmlands and site for almost 90 percent of the population; area floored principally by sands and clays of glacial origin; site of major waterways, railroads, principal highways, and centers of population; bedrock exposure, principally of Late Cambrian and Early and Medial Ordovician carbonate rocks, concentrated in fields and along streams.

(3) **Taconic Uplands** — partly forested, essentially north-south trending smooth hills of moderate relief, ranging from 400′ to 800′ elevation although in the southeastern part of the Hartford Quadrangle elevations of 900′ to 1,100′ are common; highest peak (1,293′) is the unnamed hill 4 miles south of Hartford and north of Hall's Pond; Thorn Hill (1,163′) six miles east-southeast of Whitehall, is the highest named peak in the Taconic Uplands portion of these quadrangles; widespread, but spotty, bedrock exposure of folded Early to Late Cambrian and Early to Early-Middle Ordovician shales, slates, argillites, and graywackes; north-south grain of the rocks tends to form a trellis pattern in the drainage.

The principal north-south thoroughfares are: I-87 (Adirondack Northway), U.S. 9, U.S. 4, and N.Y. 40 whereas the principal west-east ones are N.Y. 22, N.Y. 149, N.Y. 254, N.Y. 196, and N.Y. 197. A blanketing network of county and town roads makes access to the region relatively easy. The mapped area is crossed, in a north-south direction, by the Delaware & Hudson Railroad. Formerly, a branch line extended from Glens Falls to Lake George and this was a popular tourist run in the 19th and early 20th centuries; the trackless bed of this branch is now utilized as a bikeway in Lake George State Park. One airport, the Warren County Airport, two miles north of Glens Falls, handles small commercial and private planes.

According to the 1980 census, Warren and Washington Counties had remarkably close populations, 54,854 and 54,795, respectively. The populations of the political subdivisions are broken down as follows:

City	—	Glens Falls	15,897
Village	—	Fort Ann	509
		Fort Edward	3,561
		Hudson Falls	7,419
		Lake George	1,047
		Whitehall	3,241
Townships	—	Argyle	2,847
		Dresden	559
		Fort Ann	4,425
		Fort Edward	6,479
		Granville	5,566
		Hartford	1,742
		Kingsbury	11,660
		Lake George	3,394
		Queensbury	18,978
		Whitehall	4,427

A small segment of Saratoga County occurs in the mapped region south of the Hudson River. For completeness, the population of Moreau Township is 11, 188 and that of the village of South Glens Falls is 3,714.

Figure 12

GENERALIZED GEOLOGIC-TECTONIC MAP FOR THE GLENS FALLS-WHITEHALL REGION, NEW YORK

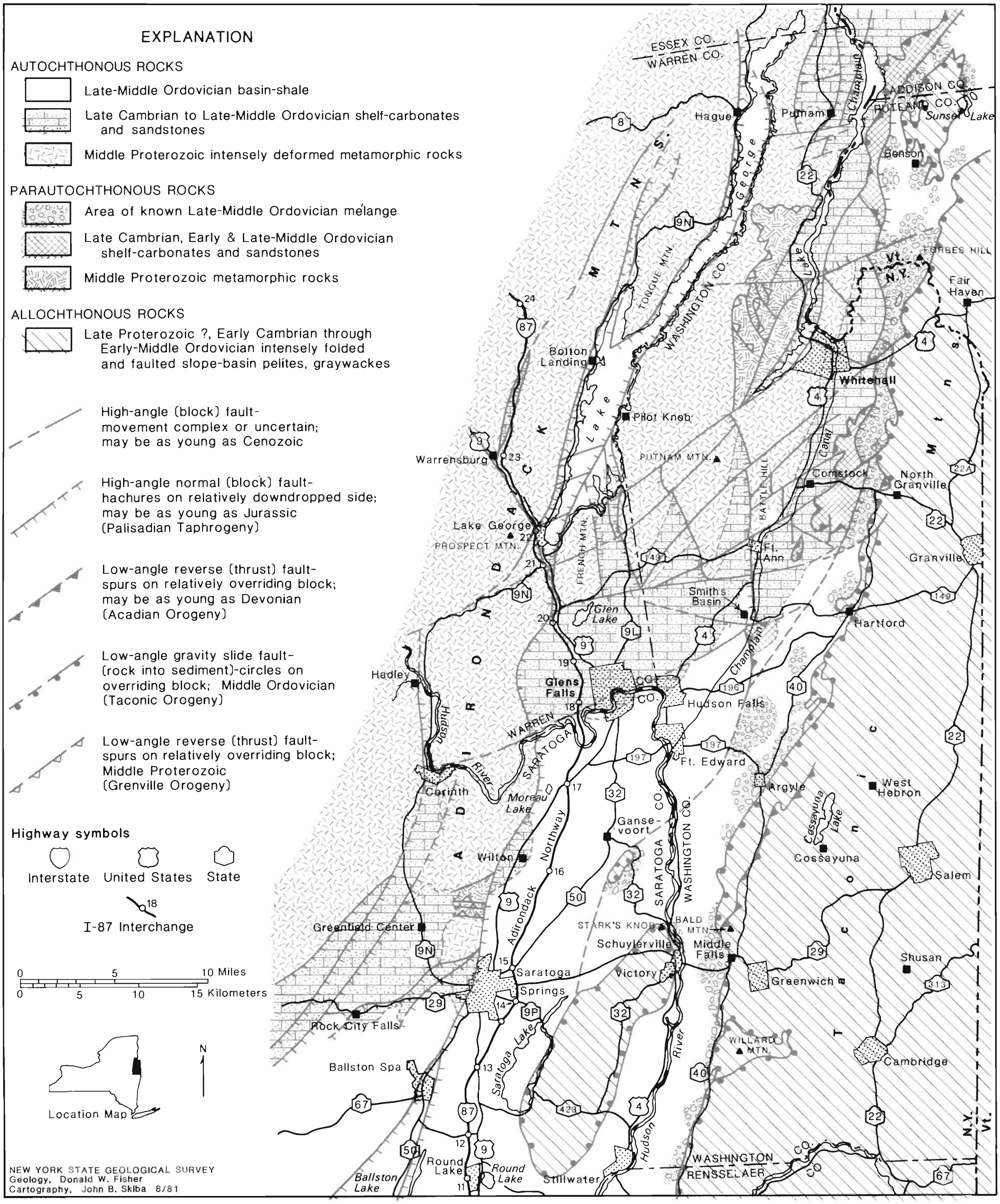


Figure 12. *Generalized geologic—tectonic map for the Glens Falls— Whitehall region, New York.*

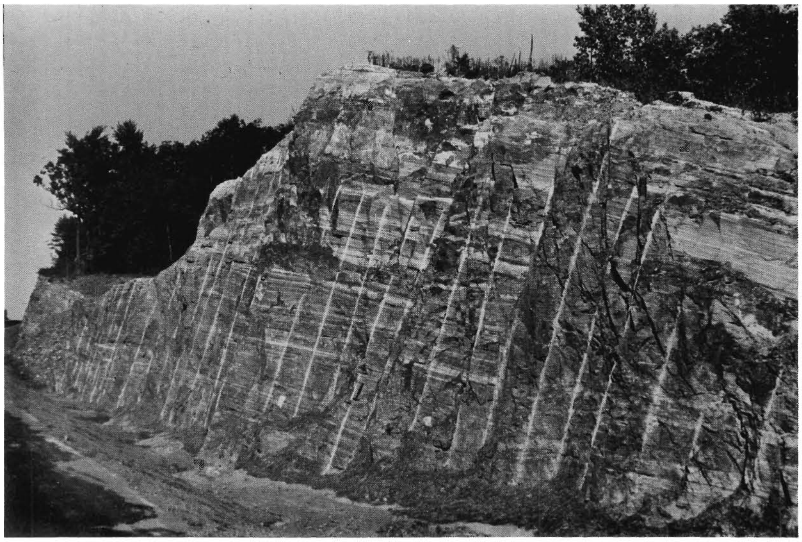
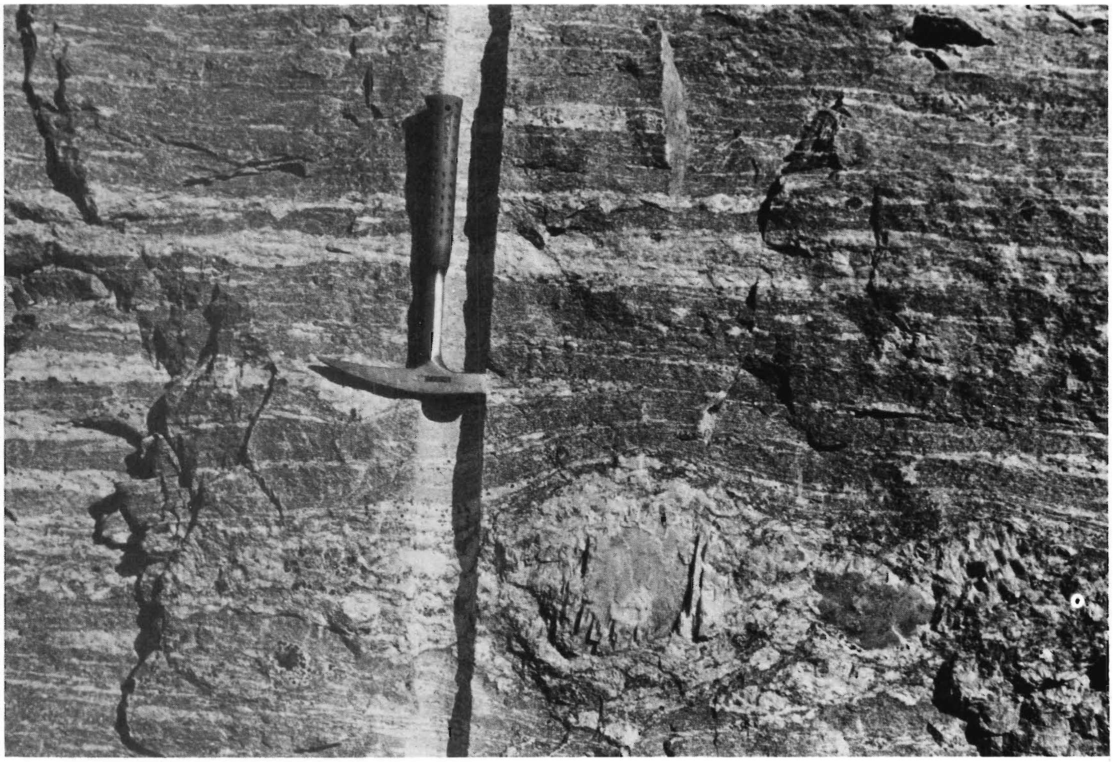


Figure 14. *Hague Gneiss, along east side of U.S. 4, north of intersection with N.Y. 22 at Comstock.*

Figure 13. *Pharaoh Mountain Formation. Charnockitic gneiss; abandoned quarry north of N.Y. 22 behind Highway Department Garage, 1.2 miles northwest of Whitehall.*

Figure 15. *Close-up of Hague Gneiss, along east side of U.S. 4, north of intersection with N.Y. 22 at Comstock. Note large inclusion of feldspar to lower right of hammer.*



GEOLOGIC HISTORY AND PALEOENVIRONMENTS

(Use Plates 1 and 3 in conjunction with this chapter.)

The geologic history of the Lake George-Glens Falls-Whitehall area commenced more than 1,400 million years ago (mya) with the creation of the Pharaoh Mountain and Brant Lake Formations of the Piseco Lake Group. The latter, unrecognized in this area but present in quadrangles to the north and west, is regarded as a granite that intruded the older charnockite of uncertain origin, both of which were remobilized and reconstituted by intense heat and pressure. Within the adjacent Bolton Landing Quadrangle to the north, the Brant Lake Gneiss has been radiometrically dated (rubidium-strontium method on whole rock) as 1,119 ± 35 million years. The Pharaoh Mtn. charnockitic gneiss (Figure 13) is believed to be the oldest rock in New York State. Southwest of Ticonderoga, the Pharaoh Mtn. Gneiss has been radiometrically dated (uranium-lead method on zircon) as 1,130 ± 10 million years (Hills and Gast, 1964).

The Lake George Group sediments accumulated in an ancient shallow ocean over 1,100 million years ago. This sequence of sands, clays, lime muds and varying mixtures of these components were built up on an ancient continental shelf and became sandstones, shales, limestones, and mixtures of these rocks. In ascending order, the Lake George Group comprises the Eagle Lake, Paradox Lake, Treadway Mountain, Springhill Pond, and Thunderbolt Mountain Formations — mostly gneisses (Figures 14, 15). Within these, several mappable members have been recognized by Alling (1918, 1925) and these have been distinguished on the Geologic Map (Plate 1). The Lake George Group has been radiometrically dated (rubidium-strontium method on whole rock) by Hills (1965, p. 127) as 1,040 ± 40 and 1,100 ± 25 million years old. The Grenville Orogeny was a long-enduring mountain-making episode, perhaps 75 million years in length, in which several folding events and several plutonic intrusive events took place (Figure 16). The relatively thick pile of Lake George Group sedimentary rocks was intensely folded (at least four times), cross-cut by igneous intrusions (anorthosite, leucogranite, hornblende granite, gabbro) and re-melted (metamorphosed) by intense heat (750°C) and elevated pressure (8,000 times atmospheric pressure) while buried some 25 km beneath the Earth's surface. One of these intrusives, the Prospect Mtn. hornblende granite has been radiometrically dated (rubidium-strontium method on whole rock) by Hills (1965, p. 128–129) as 1,035 ± 20 and

Figure 16. *Olivine metagabbro inclusion within Prospect Mountain granitic gneiss. West side of Adirondack Northway (I-87), 1.5 miles south-southeast of Interchange 21, Lake George Village.*

Figure 17. *Pegmatite dike cutting olivine metagabbro along east side of Adirondack Northway (I-87), 2.3 miles north-northwest of Interchange 22, Lake George Village.*

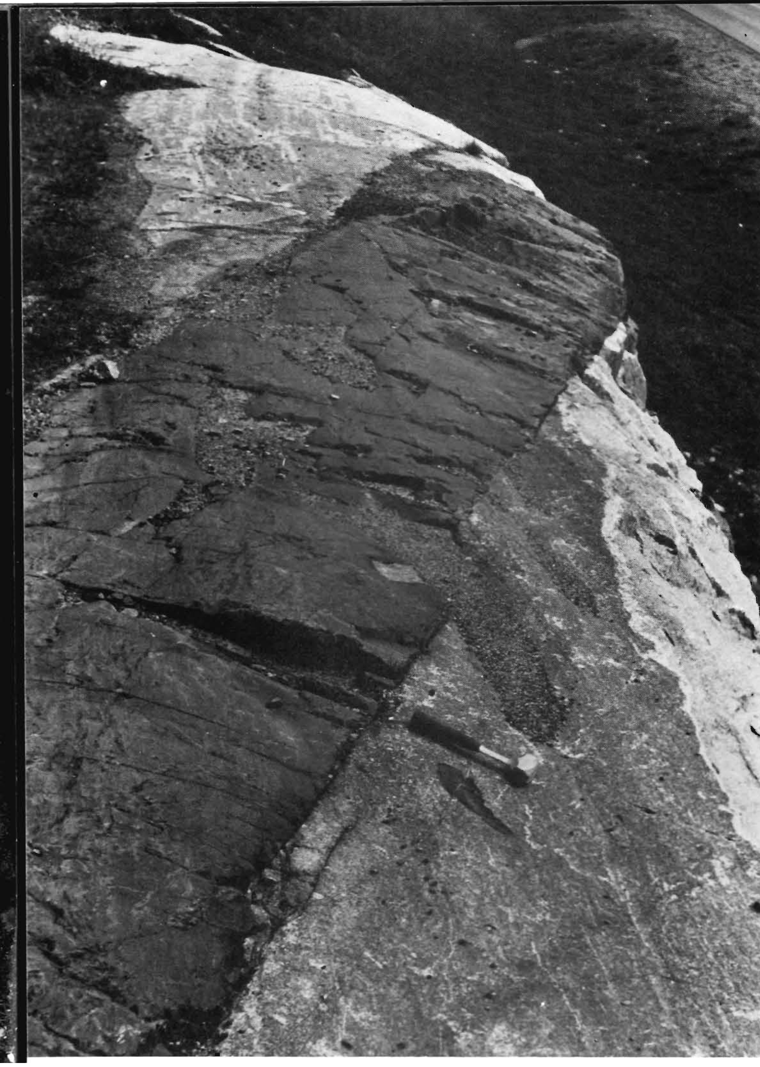


Figure 18. *Diabase dike cutting Bryant Lake Marble. Along west side of U.S. 4 and N.Y. 22, 5.5 miles north-northeast of Fort Ann. Note inclusion in marble near hammer.*

1,092 ± 20 million years. And one must remember that the older Piseco Lake Group was undergoing metamorphosis at this time, too. As a parting gesture of the crustal disrupting Grenville Orogeny, the resultant quartzites, marbles, schists, gneisses, metanorthosite, metagabbro, and granitic gneisses were intruded, about 930 mya, by relatively thin quartz-rich pegmatite granite dikes (Figure 17.)

During the subsequent 400 million years of the Late Proterozoic, high-angle (normal) block faulting and diabase dike intrusion (Figure 18), accompanied by frequent earthquake and volcanic activity, and prolonged erosion modified the landscape. Deepening rift valleys received thick, poorly sorted sediments from neighboring uplands. The widened rifts split the existing single tectonic plate in two, giving rise to an enlarging sea, termed Iapetus, between them. The two plates were to slowly drift apart until about 465 mya. Land-derived sediments came to rest within the deepening and widening basins. A few isolated deposits in the northern Adirondacks may represent accumulations at the foot of ancient fault scarps; they may be interpreted, alternatively, as glacial deposits. Whatever their cause, there is surprisingly little rock record for this relatively long interval of time. This suggests long and effective erosion. During Late Proterozoic, Early and Medial Cambrian times northern New York was presumably a land surface undergoing extensive erosion (Figure 19) much like the basin and range of Nevada and Utah today.

Figure 19. *Unconformity. Late Cambrian Potsdam Sandstone, dipping 11°E, on Precambrian Prospect Mountain Gneiss, foliation dipping 25° south-southeast, along north side of N.Y. 9L near southern end of Warner Bay, 5 miles northeast of Lake George Village.*

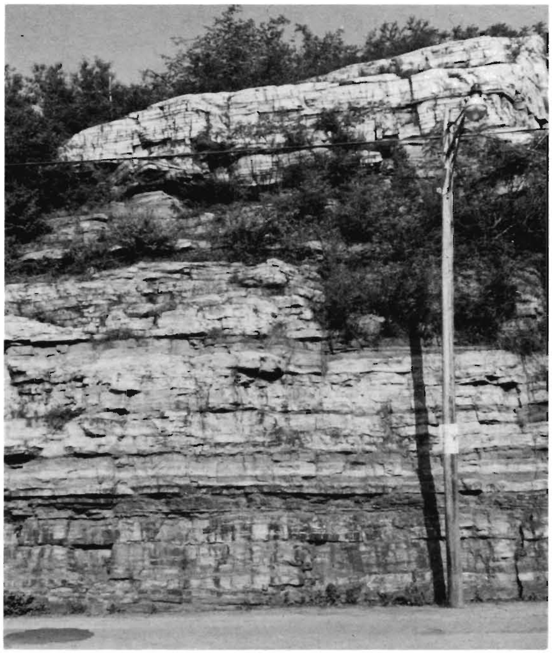


Figure 20. *Potsdam Sandstone, west face of Skene Mountain near bridge over canal, Whitehall.*

Figure 21. *Close-up of above, showing well-developed crossbedding.*

During late Cambrian time (520–500 mya), the Adirondack region was flooded, from southeast toward northwest, by a shallow sea. A broad continental shelf received quartz sands (Potsdam) (Figures 20, 21) intermixed and interbedded quartz sands and carbonates (Ticonderoga) (Figures 22, 23, 24), and purer lime muds (lower Whitehall) (Figure 25). This sea bottom had algal mats and patches that trapped fine sediment; this mixture is termed a stromatolite (of which *Cryptozoon* is a type) and is diagnostic of the intertidal zone. Trilobites, snails, and some taxonomically uncertain invertebrate animals populated the stable sea floor. The adjacent low-relief land was treeless and grassless and, thus, Late Cambrian soils lacked an anchoring apparatus and were easily washed into the bordering ocean.

The aforementioned paleoenvironment persisted into Early Ordovician time (500–465 mya) except that carbonate sediments were even more prevalent than quartz sands or silts; clay was still a very small component of oceanic sediment on the shelf. Upper Beekmantown carbonates (upper Whitehall, Great Meadows, Fort Ann, Fort Cassin Formations) were deposited amid many newer types of invertebrates. Among these were straight, slightly curved, and tightly coiled nautiloid cephalopods, high- and low-spired gastropods, new and more abundant trilobites, scarce articulate brachiopods, and the earliest ostracodes. During Early Ordovician time several withdrawals of the ocean, because of their shallowness, temporarily exposed broad expanses of the continental shelf. These short-term exposures are reflected in abrupt changes in types of sedimentation, wavy erosional surfaces (disconformities), and karst surfaces where chemical erosion has produced an undulating and pocketed tableland. These slight interruptions in the sedimentary record are found within the Whitehall, and at the bases of the Great Meadows (Figure 27), Fort Ann (Figure 28), and Fort Cassin (Figure 29) Formations; the gap at the base of the Fort Cassin represents the absence of the Jeffersonian Stage in eastern New York. Much fragmental-fossil debris and coarse textured limestone within the Sciota Member implies turbulent shallow water (Figures 30, 31).

The predecessor to the Atlantic Ocean, termed Iapetus, reached its maximum breadth at the end of Early Ordovician time. Tensional stresses changed to compressional ones at the onset of Medial Ordovician time (465 mya.) Normal block faulting probably shook the continental shelf and some folding may have occurred in more distant areas. The North American Plate was elevated, causing marine seas to recede. Chemical and mechanical erosion attacked the exposed carbonate terrane producing widened solution cracks

Figure 22. *Ticonderoga Formation. Eastern end of access road to Interchange 22, Lake George, near junction with N.Y. 9L, north side.*

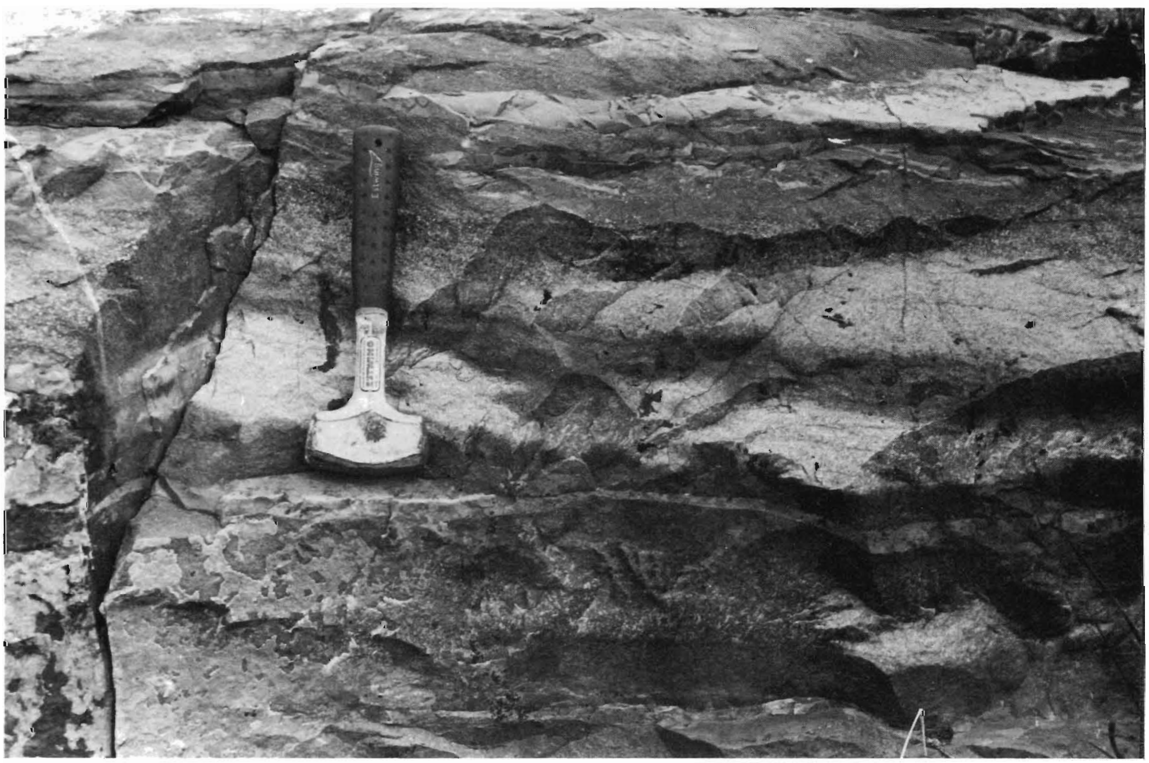


Figure 23. *Close-up of above showing alternating sandstone and dolostone layers of the transition from subjacent Potsdam Sandstone.*

Figure 24. *Same locality. Topmost dolostone bed filled with heads of the stromatolite* Cryptozoon.

Figure 25. *Warner Hill Limestone Member (type locality) of the Whitehall Formation. South side of Warner Hill, 2 miles northeast of Whitehall.*

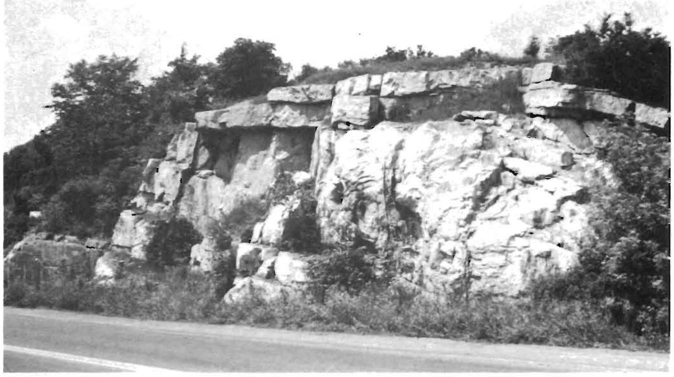
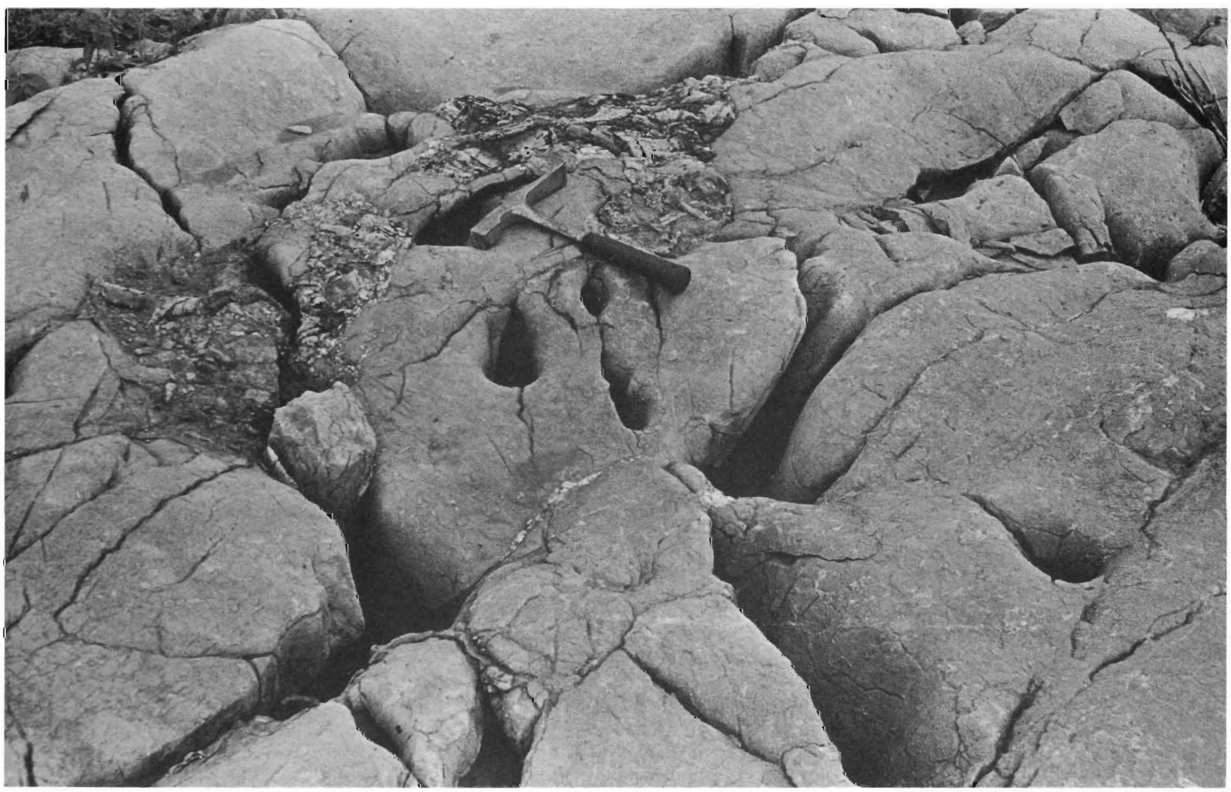


Figure 26. *Skene Dolostone Member (type locality) of the Whitehall Formation. North side of U.S. 4, south side of Skene Mountain.*

Figure 27. *Winchell Creek Siltstone Member (type locality) of Great Meadows Formation. Near Winchell Creek, along north side of Dewey Bridge Road, 3 miles east-northeast of Fort Ann. Note prominent crossbedding.*

Figure 28. *Smiths Basin Limestone Member (type locality) of the Great Meadows Formation. Field exposure north of N.Y. 149 on former Bushlea Farm. Note ancient solution cavities filled with basal breccia of overlying Fort Ann Formation.*



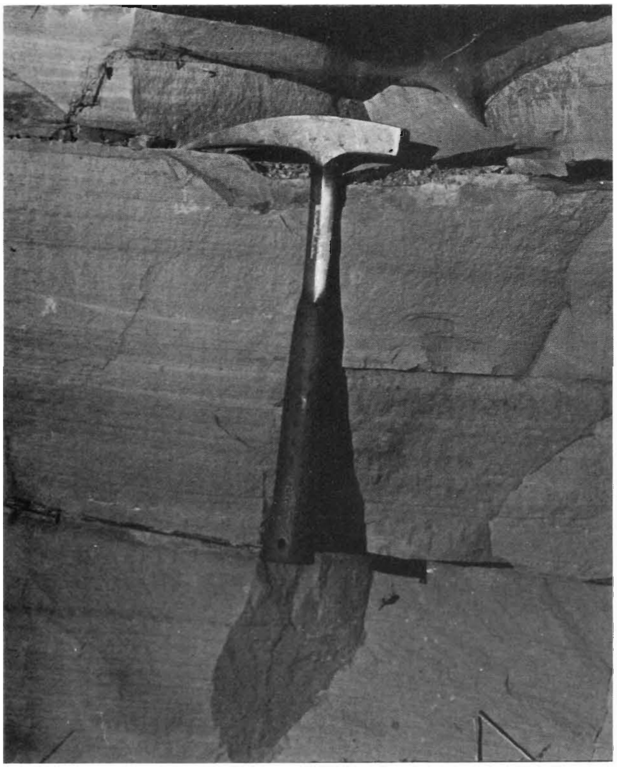


Figure 29. *Ward Siltstone Member (type locality) of the Fort Cassin Formation. Along east side of Washington County 10 (Sciota Rd.) opposite Ward Road—Thorn Hill Quadrangle.*

Figure 30. *Sciota Limestone Member (type locality) of the Fort Cassin Formation. Along east side of Washington County 10 (Sciota Rd.) near old Sciota School—Thorn Hill Quadrangle.*

Figure 31. *Close-up of Sciota lithology at type locality. Hammer points to a coarse fossil-rich lens.*

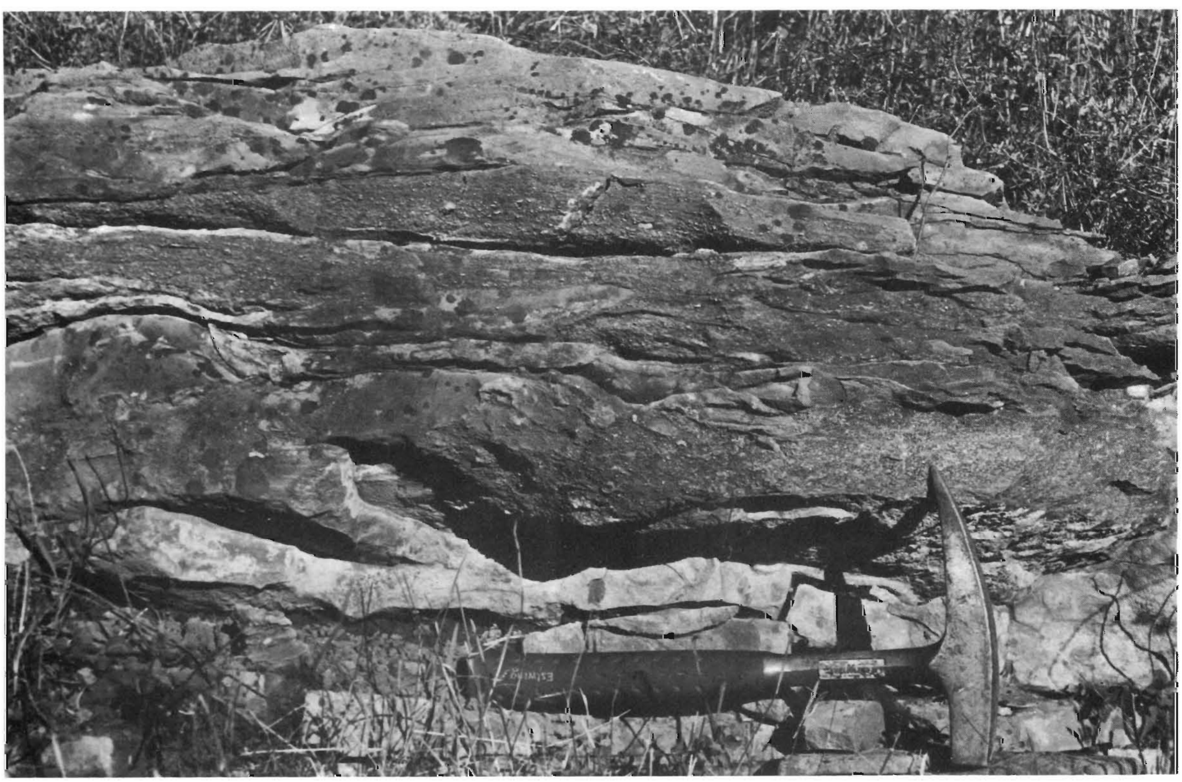


Figure 32. *Relatively large snail* (Maclurites logani.) *Dimension stone of Isle la Motte Limestone in abandoned canal lock at east edge of Fort Ann Village.*

Figure 33. *Endoceroid nautiloid cephalopod. Dimension stone of Isle la Motte Limestone in abandoned canal lock at east edge of Fort Ann Village.*

Figure 34. *Abandoned quarry, showing Amsterdam Limestone and Isle la Motte Limestone; north of N.Y. 32, south of Dix Avenue, and west of N.Y. 254, east edge of Glens Falls.*

and caves. Five to ten million years ensued in which no marine sediments were laid down in eastern North America. The sedimentary break at the close of Early Ordovician time (which erosional surface is termed the Knox Unconformity by some) is one of the most prominent in North America.

During subsequent Medial Ordovician time returning epeiric seas may have been quite restricted. At least the Early Middle Ordovician strata have a greatly limited occurrence. These Chazy Group shelf-carbonates may have had a broader distribution but were severely eroded prior to late Medial Ordovician sedimentation or the Chazy simply may have had a very restricted depositional realm. Today, Chazy rocks are confined to the Champlain Valley from Ticonderoga northward. Their slope and basin equivalents may be the Normanskill shales, although that correlation is not firmly established. Chazy carbonates are very fossiliferous with a cosmopolitan fauna of many species of brachiopods, bryozoans, sponges, newer types of trilobites, ostracodes, conodonts, cephalopods, gastropods, the earliest pelecypods (in New York), great quantities of echinoderm debris, columnals of crinoids and cystids, among the earliest conularids, and the earliest known corals. Reef mounds, constructed primarily of bryozoans, sponges, algae, and the extinct stromatoporoids, are common. The high diversity and abundance of invertebrates in Chazy strata is in marked contrast to the low diversity and sparsity of fossils in Beekmantown strata. The reason for this is uncertain but Beekmantown seas may have been much cooler. Throughout the Early Ordovician and Early Medial Ordovician, the shelf edge lay somewhere in Vermont and western Massachusetts. East of this line, clay-rich and colloidal-silica (chert) sediments were accumulating on the ancient oceanic slope, rise, and basin. Late Cambrian, Early Ordovician, and Early Medial Ordovician turbidites and slump conglomerates typify this Taconic sequence of rocks.

Transgression of Late-Medial Ordovician (450–440 mya) seas over the eroded older strata was extensive. Black River and Trenton Group carbonates are thin, blanket-type and represent many differing ecological niches, each diagnosed by specific physical and organic properties. The environments ranged from supra-tidal to distal subtidal shelf or proximal slope. Within the relevant mapped area, sedimentation began with the accumulation of the Isle la Motte Limestone (Figures 32, 33, 34) in quiet waters, followed by deposition of the Glens Falls Limestone (Figure 35) in more agi-

Figure 35. *Isle la Motte Limestone and Glens Falls Limestone. North wall of abandoned Jointa Quarry, Glens Falls.*

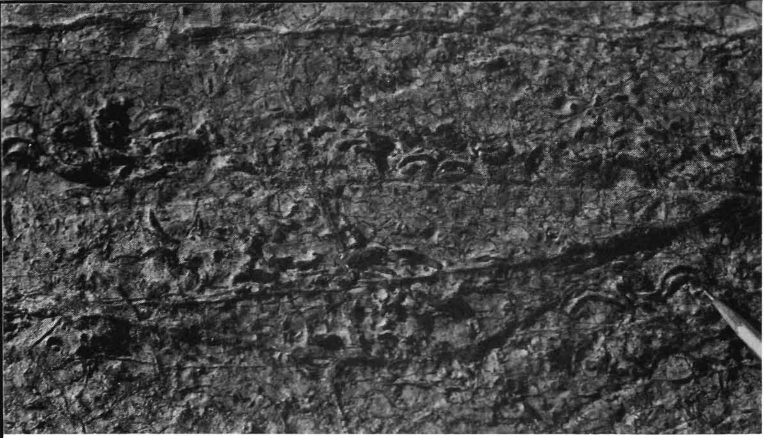


Figure 36. *Cross sections of brachiopods* (Triplesia?) *Isle la Motte Limestone, north side of Upper Turnpike, 3 miles south-southeast of Whitehall.*

tated and turbid waters. Great quantities and kinds of brachiopods (Figure 36) typify the Isle la Motte and Glens Falls Limestones, with lesser numbers and kinds of trilobites and bryozoans. Mollusks tend to be subordinate. Carbonate sedimentation on a firm substrate gave way to thick accumulation of black mud on an unstable substrate. Pelagic graptolites floated in all bathymetric zones within a developing basin on the site of the previous shelf. The Snake Hill Shale (Figure 37) represents the erosional debris shed from the rising Taconic Mountains to the east. Thus, a "teeter-totter" effect was present with the ancestral Green Mountains and Berkshires rising as the Snake Hill basin deepened. Dramatic and catastrophic events, probably heralded by intensified earthquake and volcanic activity, accompanied much faulting both on the shelf and gravityslide faulting into the newly created basin and thrust slicing offshore beneath the surface. A mountain-making episode was in operation. This **Taconic Orogeny** may be conveniently separated into three distinct phases: (1) **Bonnian Phase,** (2) **Vermontian Phase,** (3) **Hudson Valley Phase.**

The **Bonnian Phase** began in the east and is well documented in Newfoundland. Its effects are less well known in eastern New York. It is thought that at this time the Normanskill sediments were accumulating east of the present limits of New York State and adjacent to an island arc system (much like the Japanese Islands) which developed within a contracting Iapetus Ocean. A remnant of the volcanic rocks associated with this island arc activity is Stark's Knob, a volcanic pillow lava at Northumberland just north of Schuylerville. Contemporaneously and subsequently, the ancestral Berkshires and Green Mountains were elevated by block-faulting and during the **Vermontian Phase** the covering strata spalled-off and avalanched down the western flank of the newly uplifted mountains into the mud of the deepening Snake Hill Basin. The plummeting vari-sized and vari-type rocks came to rest in differing positions within the churned-up syrupy mud. The resultant "plums-in-a-pudding" conglomerate is termed mélange, wildflysch, or chaos. This gravityslide type of sedimentary-tectonic deposit distinguishes the "Low Taconics" and the Vermontian Phase of the Taconic Orogeny.

The Snake Hill Basin continued to receive detritus from the now alpine-like Taconics. Eventually the basin filled with cleaner, well-sorted clastics (molasse) of graywacke, sandstone, and shale represented by the thick wedge (minimum of 2,500 feet) composed of the Schenectady Formation. The tremendous weight exerted by the Schenectady and any overlying delta sediments of the Lorraine Group and Queenston Formation depressed the crust, giving rise to additional folding, westward thrust faulting accompanied by slivering along faults, and metamorphism. Fracture

Figure 37. *Snake Hill Shale. Non-calcareous, deformed, and cleaved; in abandoned shale pit on east side of Washington County 42, 2.5 miles east of Fort Edward.*

cleavage, so well displayed in the strata of the Taconic Sequence, is believed to have been imparted at this time. This conjunction of tectonic processes constitutes the **Hudson Valley Phase** of the Taconic Orogeny. In summary, Medial and Late Ordovician times were a tumultuous period in the geologic history of eastern New York and New England, a time when the Taconic Mountains grew and reached their zenith.

No rock record younger than the Snake Hill Shale exists within the mapped area save for some narrow diabase dikes, which may be Mesozoic in age. From neighboring areas to the south of the Mohawk Valley, we know that Silurian and Devonian seas flooded eastern New York and left their fossiliferous sedimentary record in over 3,000 feet of strata. Whether these rocks extended into the mapped area is unknown but presumed. Next there followed millions of years of geologic history unrecorded in this area. While coal swamps were forming in Pennsylvania, 280 to 255 million years ago, and while dinosaurs were scurrying about in the Connecticut Valley, about 200 million years ago, the southern Champlain Valley area was presumably higher land.

The next geologic event to have affected the eastern New York region was extensive block faulting creating linear highlands and basins. This Late Triassic-Early Jurassic tensional event is termed the **Palisadian Taphrogeny.** Old faults were reactivated. Late Cretaceous uplift and peneplanation followed.

Cenozoic uplift, faulting, and peneplanation were widespread. Doming of the Adirondack Mountains may have initiated during Cretaceous time and accelerated during Eocene to Miocene Epochs. One must remember that, whereas the rocks of the Adirondacks are the oldest in the State, the mountains themselves are probably the youngest within the State.

The most recent major geologic event to have affected New York State was a climatic one, the bone-chilling Ice Age, of 200,000 to 15,000 years ago (Pleistocene Epoch.) Ebbing and flowing continental glaciers, up to one mile thick, destroyed, modified, and constructed topographic features and soils. Rock-derived soils were assimilated within the advancing ice and redistributed elsewhere. Incorporated rocks left their imprint by scratching, gouging, and polishing the now bare bedrock (Figures 38, 39.) The topography was smoothed-off. Eventually the continental ice sheet reached its maximum southern extent on Long Island, and began its slow, nonuniform retreat northward by melting. Withdrawing over the previously scoured landscape brought about more modifications of the landscape, mainly, as depositional features formed both in and out of temporary bodies of water. Accordingly, some deposits are poorly sorted and some are well sorted. The gravels, sands, and clays, so prevalent in the Glens Falls area, are products of glacial erosion or deposition. They do not represent the weathered detritus of the rocks beneath them. For details of sediment type and distribution, the reader is referred to Connally (1973) who distinguished ten sediment units on a colored map of the surficial geology of the Glens Falls region (scale 1:48,000); the Whitehall and Thorn Hill Quadrangles were excluded.

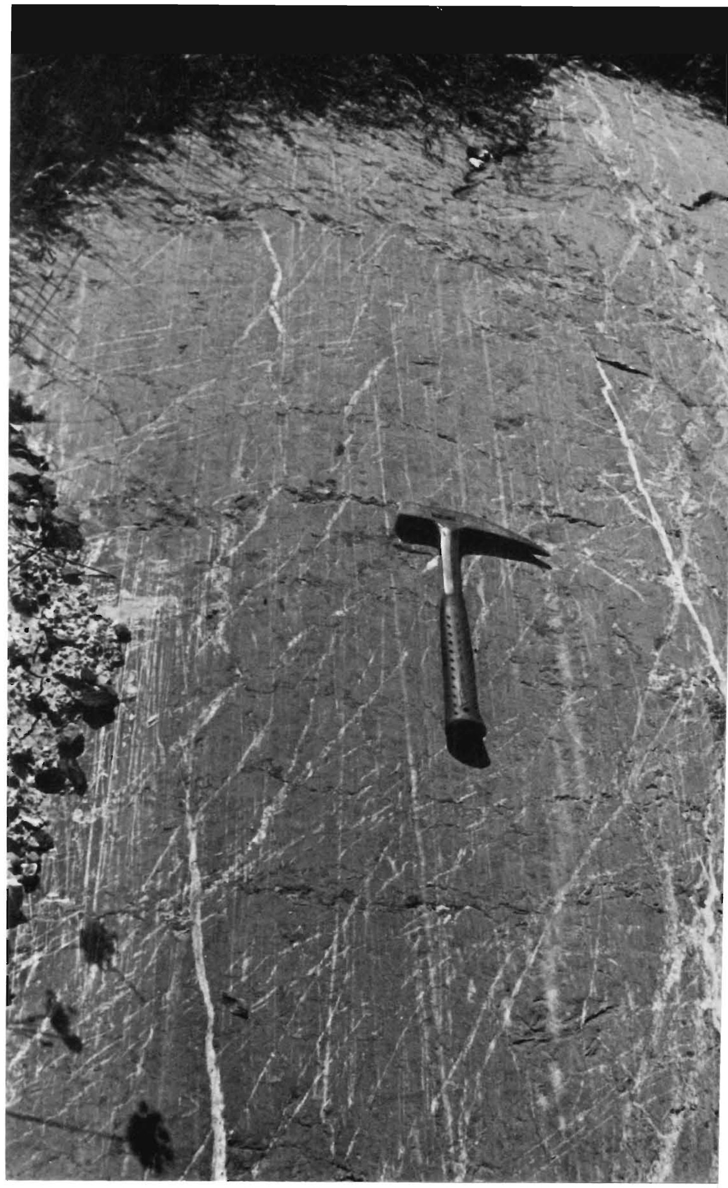


Figure 38. *Glacial striations. On limestone block in mélange near intersection of Abair and Gould Roads — Thorn Hill Quadrangle. These north-south rulings are caused by rocks embedded in the sole of the ice as it scratched the underlying calcite-veined limestone in its southward travel.*

The Pleistocene Ice Age had a pronounced impact upon plant and animal life of the affected region. Subtropical vegetation progressively gave way, to a boreal tundra fauna. Animals moved elsewhere, grew heavier coats, or perished. Following the retreat of continental ice, musk oxen, dire wolves, barren-ground caribou migrated northward, but the elephantine mammoths and mastodons ceased to exist. Humans have occupied the region for over 5,000 years. Archeological sites at Assembly Point on Lake George date back to the Archaic Stage (Vergennes Substage) of cultural sequences of human habitation. The "Fort Ann Chert," so widespread as projectile points at archeological sites in Warren and Washington Counties, was obtained by former Indian cultures from the Fort Edward Dolostone Member of the Great Meadows Formation and from the Finch Dolostone Member of the Whitehall Formation.

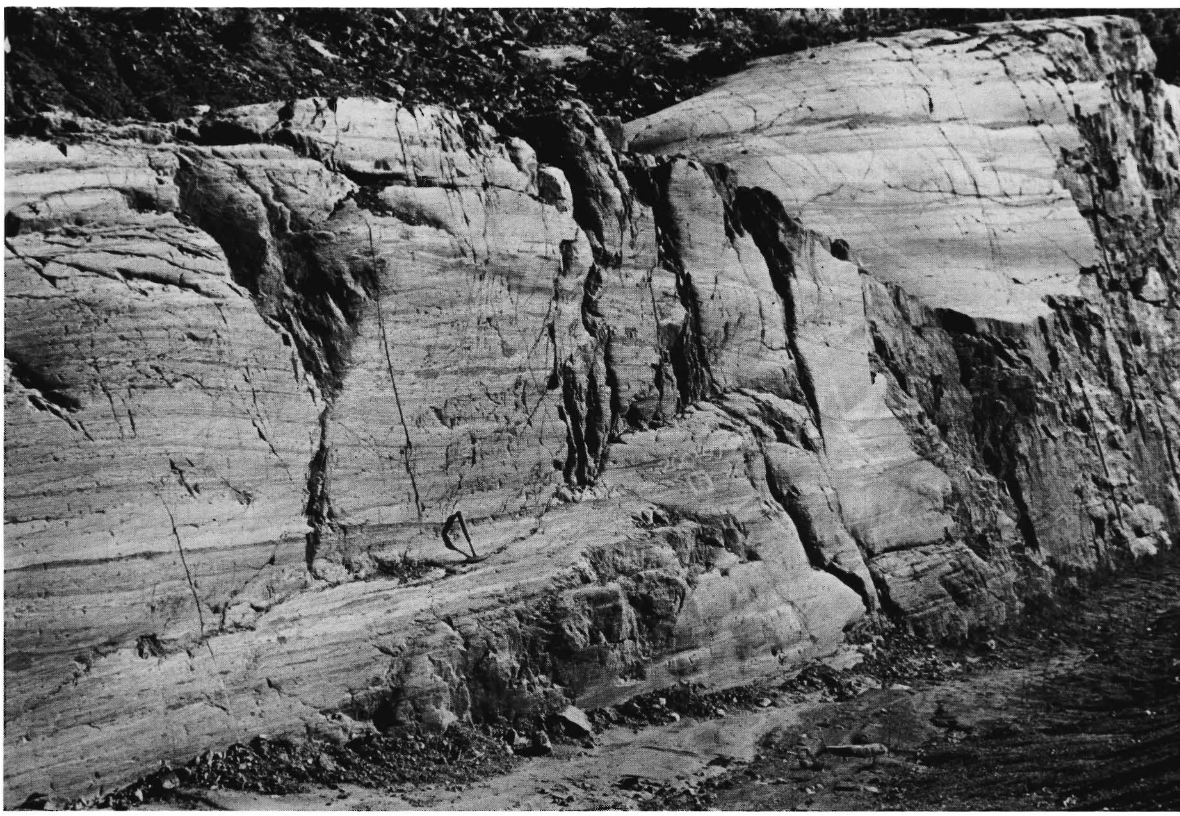


Figure 39. *Glacial scouring and polishing. On Hague garnet-gneiss, east side of U.S. 4, 3.4 miles northeast of Fort Ann. Note plucking effect on right side of photo indicating glacial movement from left (north) to right (south).*

MIDDLE GRANVILLE SLATE
(new—Kidd, W.S.F., Delano, L.L., and Rowley, D.B., in Fisher, D.W., this publication)

Justification:

Previous mapping has confused dark slates and limestones above and below this unit. As a result, this unit has been included, in different places, in two different formations. Definition of this unit, and that of the Browns Pond Formation below it, overcomes this confusion.

Lithologic description:

Name proposed for green, purple, maroon and lesser pale to medium grey slates, extensively quarried, that lie *above* dark grey to black slates containing abundant limestones and lesser dark greywacke and orthoquartzite (Browns Pond Formation), and *below* sooty black slates containing common dolomitic arenites and quartzites, and local limestones (Hatch Hill Formation). The Middle Granville Slate weathers a distinctive and diagnostic tan color. It contains locally, in its lower to central portions, thin interbeds of grey micrite, in many places reduced to layers of disconnected nodules. Rare beds of pebbly limestone breccia and of calcarenite, up to 1 meter thick, are also found in the lower half. Phosphatic pebbles are present in these coarser limestones. Sections lacking purple and maroon slates and with scant limestones are common, particularly in the western portion of the northern Taconic Allochthon.

Contacts:

The upper contact of the unit is placed at the point where green or purple or pale-medium grey slates pass up into sooty, fissile black slates. This change is commonly sharp, or occurs over less than 1 meter thickness, but in some places is transitional over 1–3 meters.

The lower contact is placed where medium to dark grey slate changes upward to green slate. In most places this is a sharp contact or a transition over less than 1 meter thickness. At this position there is commonly a limestone breccia (which may be several meters thick); this breccia is included within the underlying Browns Pond Formation, the contact being placed at the top of the breccia, under the lowermost green slate.

Type section:

The type section is defined as the quarries and adjacent outcrops 300 to 1500 meters NNW of the bridge over the Mettawee River at Middle Granville [Granville 7½′ quadrangle]. Because further quarrying, degradation of abandoned quarries and future dumping of waste slate may obscure or remove features that can be seen at present, and because the upper contact is not well exposed in the type section, the following reference sections are provided to avoid future ambiguity arising from physical alterations in the type section.

1) A presently non-working quarry, 2.0 miles N24°E of the bridge over the Mettawee River at Truthville, at the west side of Holcombville Road. This section is described in Rowley, Kidd and Delano (1979). [Granville 7½′ quadrangle]

2) Outcrops in the field west of Holcombville Road up to the nearby southeastern shore of Browns Pond, on the northern side of the hill enclosed by 600 ft. contour. (3.15 miles N13°E of the bridge over the Mettawee River at Truthville). [Granville 7½′ quadrangle]

3) Outcrops adjacent to Hills Pond Road in the area where the 800 ft. contour crosses the road 0.3 mile north of the northern end of Hills Pond. [Thorn Hill 7½′ quadrangle]

4) Outcrops in the fields just west of Lee Road, in a belt extending up to 0.4 mile north of the southern of the two points where the 800 ft. contour crosses the road. (Lee Road is located 1.5 miles due west of the intersection of New York Routes 149 and 22 at the southern end of the town of Granville) [Granville 7½′ quadrangle]. All of these reference sections have sufficient outcrop to demonstrate the nature of the unit and the adjoining parts of the units above and below.

Thickness:

In the type section, an apparent thickness of up to about 95 meters is present but undetected repetition by minor folds may inflate the thickness here. A typical thickness of this unit in the Granville and Thorn Hill quadrangles is about 50 meters. Locally, as little as 10 meters may be present, and the unit is generally thin towards the western edge of the Allochthon in this area.

Age:

Fossils of the *Elliptocephala asaphoides* fauna have been recovered from limestones in the lower and middle parts of the unit (Dale, 1899; Theokritoff, 1964) indicating an Early Cambrian Age.

Synonomy and correlation:

This unit has previously been mapped both as part of the Mettawee Slate (upper part of the Bull Formation) and as part of the West Castleton Formation, by Theokritoff (1964) and Zen (1961). This is because these authors did not recognize the existence of the Browns Pond Formation and confused it, in places, with the basal part of the Hatch Hill Formation (the part designated by them West Castleton Formation). The unit was mapped as part of the Cambrian Roofing Slate by Dale (1899) who unfortunately misplaced this portion below rather than above the level of the Browns Pond Formation, one of whose distinctive lithologies (Black Patch Grit) he did recognize.

Farther south, it may be equivalent to an un-named greenish shale listed by Dale (1904) at the top of his Cambrian section, not discussed or named by Ruedemann (1914), in the Taconic sequence of Rensselaer and Columbia Counties. It is equivalent to an interval within the lower portion of the Germantown Formation of Fisher (1962).

GEOLOGIC AGE AND CORRELATION

Aside from determining the geologic history in a particular area, one of the primary goals of the geologist is to ascertain the age of the rocks and be able to correlate the local rock sequence with adjacent and far-away areas. Absolute age of rocks may be determined by radiometric dating, using isotopes of uranium, rubidium, potassium, or carbon. However, if the rock does not contain minerals that possess these isotopes then an absolute age is impossible to determine with the presently known methods. Relative ages of rocks are easier to ascertain and these are based on two fundamental laws. These are:

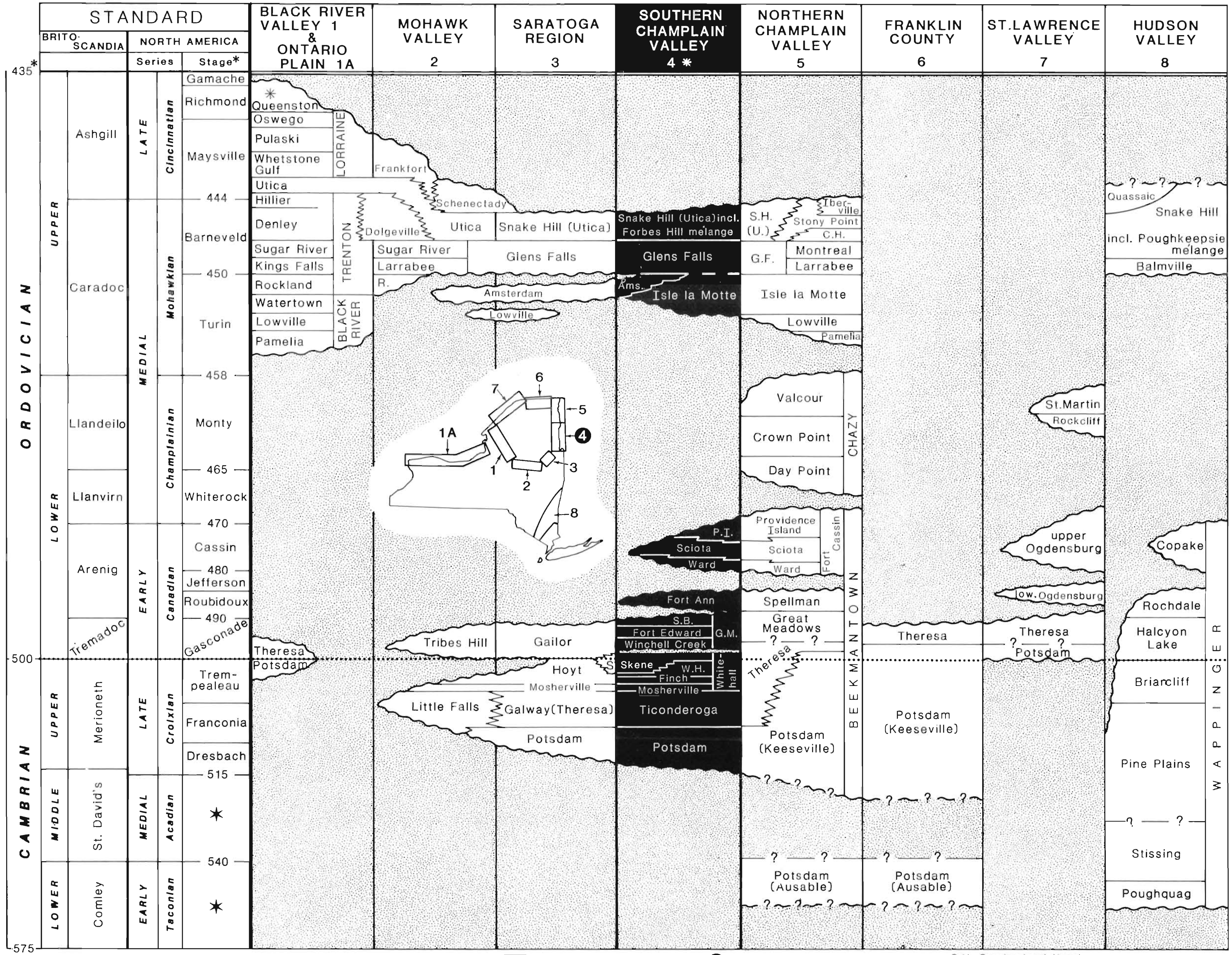
(1) **Law of Superposition,** which states, that in any undeformed pile of sediments or sedimentary rocks, a layer or bed of rock is younger than the bed below it and older than the bed above it, and

(2) **Law of Biotic Succession,** which states that animals and plants succeed themselves in an orderly and determinable sequence and that each interval of time (stage) can be reliably recognized by the diagnostic fossils within it.

Thus, a biostratigraphic zonation may be constructed using detailed knowledge of evolutionary changes within a specified fossil group over a period of time. Such zonations form the framework for correlation charts. The correlation chart shown (Figure 40) equates the Cambrian and Ordovician rocks of New York State to those regions where exceptional rock sequences and fossil zonations have been studied in other parts of North America and elsewhere in the World. In this way gaps in our geologic time scale are being filled by paleontologists and stratigraphers throughout the World. Additional paleontological research fortifies our framework and, thus, our correlations. Animals that were relatively short-lived, mobile, bottom dwellers, swimmers, or floaters constitute the best tools for correlation. Fixed bottom dwellers and those animals that changed little over millions of years provide useful data for reconstructing ancient environments but are of limited or risky use for correlations. In New York, the most utilitarian fossils for Cambrian and Ordovician correlations are trilobites, nautiloid cephalopods, conodonts, and graptolites. Brachiopods, bryozoans, corals, crinoids, cystoids, stromatoporoids, and snails locally may be useful for correlation but normally these types of fossils furnish more information on paleoenvironments.

Figure 40

CORRELATION — AUTOCHTHONOUS CAMBRIAN-ORDOVICIAN STRATA IN NEW YORK



NEW YORK STATE GEOLOGICAL SURVEY
Compilation Donald W. Fisher
Graphics John B. Skiba 11/81

* numerals, millions of years ago
✳ present in 1A only

hiatus, rock absent
✶ Stages not established

✳ Section for Glens Falls-Whitehall region

C.H. Cumberland Head
S.B. Smith Basin
W.H. Warner Hill

Figure 40. *Correlation — Autochthonous Cambrian-Ordovician strata in New York.*

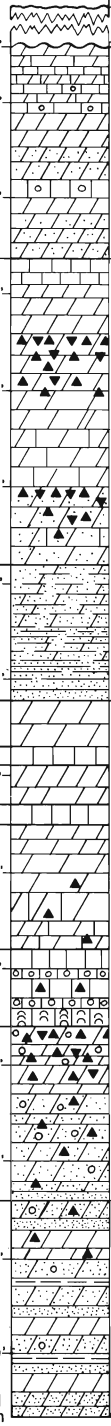
Figure 41

IMPERIAL PAPER COMPANY WELL

Warren County, Queensbury Township, Hudson Falls Quadrangle

Surface elevation 265'. Location: 8400' S43°20'–5850' W73°35'

Completed 1940



STRATIGRAPHIC UNIT		LITHOLOGY
Overburden		*Sand, Silt, Clay*
FORT ANN FORMATION (110')		mottled dolomitic limestone & calciticdolostone, with thin purer dark gray limestone interbeds, gastropod fragments, locally oolitic (o), calcite rhombs 90'-100' dark gray to black fine grained limestone, oolitic 100'-130' sandy & silty calcitic dolostone
GREAT MEADOWS FORMATION (230')	SMITHS BASIN LS. MEMBER	light gray, fine-grained limestone
	FORT EDWARD DOLOSTONE MEMBER (145')	145'-170' vuggy, light gray dolostone, quartz crystals, dolomite rhombs 170'-195' abundant dark gray to black chert (▲), vuggy, light-medium gray dolostone, some quartz crystals 195'-250' mottled, medium-dark gray slightly cherty calcitic dolostone, vuggy, many dolomite rhombs 250'-290' abundant black chert, mottled dark gray calcitic dolostone, some quartz grains
	WINCHELL CREEK SILTSTONE MEMBER (70')	interbedded sandstone, siltstone & gray shale with dolomitic & calcitic cement, pyritic
WHITEHALL FORMATION (260')	SKENE	crystalline, medium to coarse grained tan to light gray dolostone, vuggy
	*RATHBUNVILLE SCHOOL LIMESTONE MEMBER	fine-grained, light gray limestone, scarse fossil fragments
	SKENE	same as Skene above
	*STEVE'S FARM LIMESTONE MEMBER	fine-grained, light gray limestone
	SKENE DOLOSTONE MEMBER	same as Skene above but is increasingly finer grained, darker gray, slightly cherty, calcitic & silty, vuggy
	WARNER HILL LS. MEMBER (40')	fine-grained light gray limestone & dark gray limestone, oolitic, slightly cherty, light gray, stromatolitic (⌒), few trilobite fragments
	FINCH DOLOSTONE MEMBER (90')	abundant dark gray to black chert in light to medium gray dolostone, locally oolitic & sandy, many quartz crystals **base not well defined**
? — ?	? — ?	? — ? — ?
TICONDEROGA FORMATION (113'+)		interbedded medium to dark gray dolostone with frosted quartz grains & dolomitic sandstone with few silty shale layers, few oolites & quartz crystals, upper 50' sparsely cherty

NEW YORK STATE GEOLOGICAL SURVEY — Interpretation: Donald W. Fisher, 1969, recast 1981 — Graphics: John B. Skiba 1/82

*unit probably thinner, sampling interval is 10'

Figure 41. *Imperial Paper Company Well.*

Figure 42

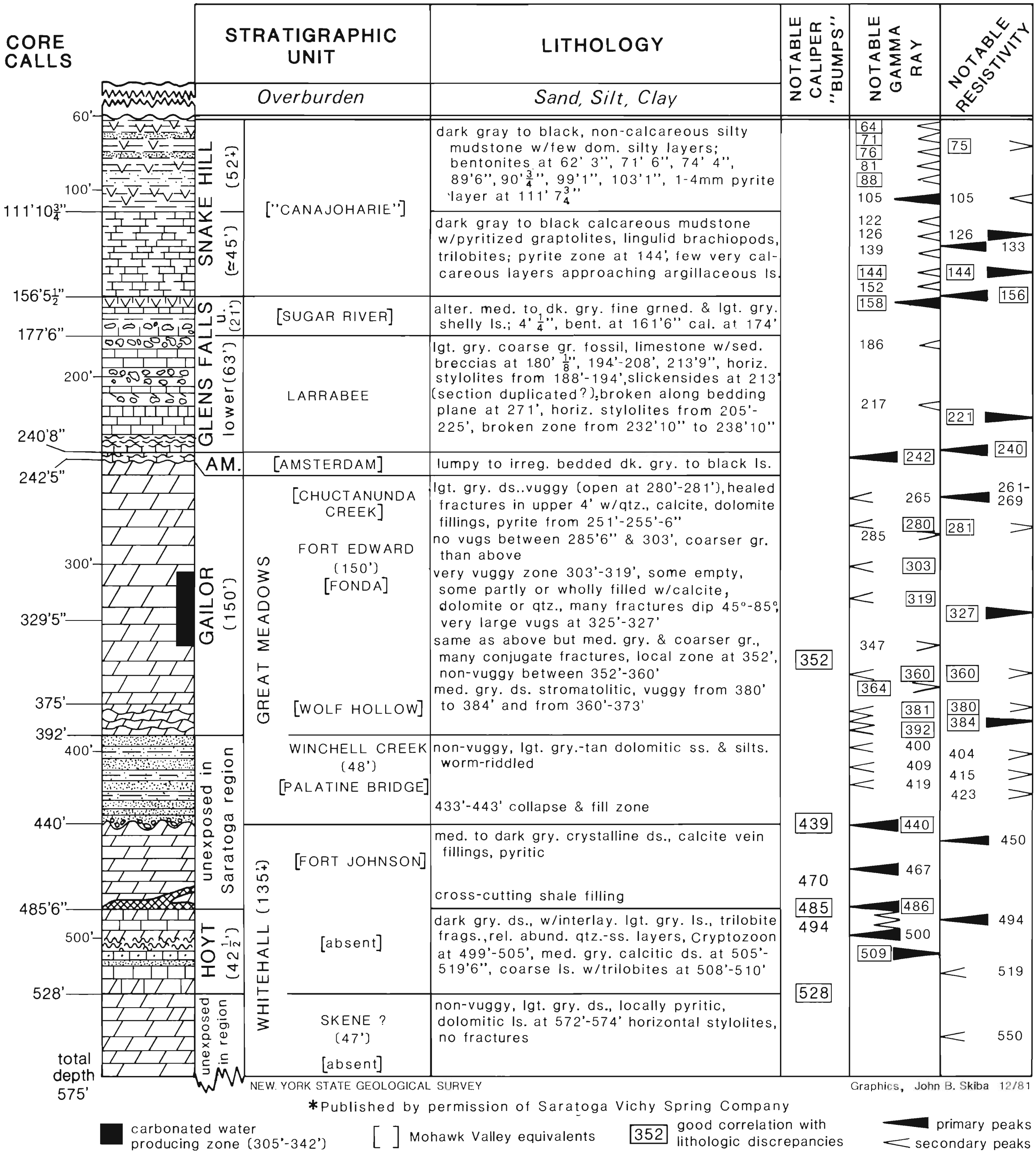
SARATOGA VICHY SPRING COMPANY CORE*

Saratoga County, Milton Township, Saratoga Springs $7\frac{1}{2}'$ Quadrangle

West bank of Geyser Brook, North of Geyser Road

Surface elevation 280′, Latitude 43°3′32″–Longitude 73°48′38″

Cored Jan. 24 to Feb. 2,1979



Logged & interpreted by Ennis P. Geraghty & Donald W. Fisher,1979; additional interpretation by Fisher,1981

Figure 42. *Saratoga Vichy Spring Company core.*

SUBSURFACE STRATIGRAPHY

General Statement

Within the mapped area, well-drillers seldom penetrate the surface deeper than 400 feet in prospecting for domestic or industrial water supplies. Occasionally, boreholes are made for other purposes such as seeking subsurface accumulations of oil, natural gas, or carbonated water, locating suitable subsurface repositories for toxic or non-toxic liquid waste disposal, or for economic mineral exploration. Whenever these deeper tests are made, the potential is great for learning more about the subsurface attitude, distribution, and kind of rock. This information is especially critical where surface exposure of bedrock is scant or lacking. Obviously, the care and completeness with which samples of subsurface strata are obtained and kept is vital in enabling the geologist to make maximum use of them. Those geologists who are concerned with mapping the kinds and distribution of bedrock are always alert to the availability of well records in an area under investigation for they furnish information toward making a more precise bedrock map in regions where the bedrock is concealed by unconsolidated overburden (surficial deposits).

Within the mapped area, less than 10 wells are known that were drilled deeper than 400 feet. Most of these are clustered near Smiths Basin, Fort Ann, and east of Whitehall. To my knowledge, only one well was specifically drilled as an oil test. The site is 2¾ miles southeast of Smiths Basin on the George Benton Farm, and reached a depth of 842 feet in the Beekmantown Dolostone. No oil was discovered and only very small quantities of water were found. To date, the deepest borehole known in the mapped area is ½ mile south of Fort Ann, on the Lewis Mesnik property, which bottomed at 990 feet in "red granite"; this hole may have crossed the Welch Hollow Fault or a branch fault of it.

In general, those wells producing water from Pleistocene gravel and sand yield larger volumes of water than do those from bedrock—where porosity and permeability are usually less. But, in some places, zones of fractures in bedrock are sufficiently extensive to yield higher than common amounts of water. A notable example of a bedrock well with an anomalously high water yield is the Standard Wall Paper Company Well at Hudson Falls, drilled to 361 feet, and producing 2,000 gallons per minute from the Beekmantown carbonate. The nearby Hudson Falls Beverage Company Well, drilled to 88 feet, yields 80 gallons per minute from the Beekmantown. Across the Hudson River from Hudson Falls, the Arkell and Smith Well, drilled to 301 feet, yields 300 gallons per minute from the Beekmantown carbonate. The proximity of the Hudson River undoubtedly exerts a prime role in furnishing recharge to these wells but closely spaced joints may also assist recharge. Another notable well producing water from bedrock is the Manning Company Well at Dewey Bridge, drilled to 175 feet and yielding 60 gallons per minute from the Potsdam Sandstone. Whereas only a handfull of wells in the mapped area yield more than 50 gallons per minute, the vast majority yield less than 15 gallons per minute. Most wells tap the Pleistocene gravels and sands.

Two deeper wells, the Imperial Paper Company Well (Figure 41) in eastern Glens Falls and the Saratoga Vichy Spring Company Well (Figure 42) at the southeastern edge of Saratoga Springs, deserve special mention and detailed analysis here. Their respective logs of well cuttings and core are previously unpublished. Both records reveal exceptionally complete and significant lithologic information while the latter has the additional benefit of geophysical logging. Their respective subsurface data greatly fortify the presumed stratigraphic relationships and correlations within the Mohawk Valley-Saratoga Springs-Glens Falls region. To date, these well logs constitute our most complete and reliable stratigraphic column of the Cambrian-Ordovician shelf carbonates along the southeastern flank of the Adirondack Mountains. Detailed information on distribution, rate of flow, and chemical analysis of ground water may be found in Cushman (1953), Heath, Mack, and Tannenbaum (1963), and Giese and Hobba (1970).

STRUCTURAL GEOLOGY

(Use Plates 1 and 2 in conjunction with this chapter.)

The rocks of the mapped region have behaved in both plastic and brittle fashions. In the former instance, folds are formed; in the latter instance faults, joints, or cleavage are produced.

Folds: Strata bend or fold under elevated temperatures and pressures relatively deeply beneath the surface or strata may crumple near or at the surface before they are consolidated. Folds result from compressional stresses within the Earth's crust. Many types and sizes of folds exist within the region. Some are measured in kilometers or meters whereas others are measured in centimeters. Some are tight, with short wavelengths and high amplitudes; others are broad, with long wavelengths and low amplitudes (Figure 43). Some folds possess vertical axial planes whereas others display axial planes that dip by varying amounts. Some folds lean so far in one direction that they are recumbent (Figure 44). And some folds are refolded, perhaps more than once, making an understanding of their chronology very difficult. Not all folds were formed at the same time. Within the Adirondack Uplands, complex folds (four or five phases of folding) were created during the Grenville Orogeny of 1,100 million years ago. But the equally complex and multiple folds within the Taconic Uplands were formed much later, about 455 to 400 million years ago. At least three separate phases of folding are known: (1) small-scale kink folds, (2) isoclinal to pseudo-isoclinal folds, on a small and large scale, with axial planes vertical to east-dipping, (3) broad, overturned, recumbent folds. By contrast, the Hudson-Champlain Lowlands show only a few open folds in the carbonate rocks with

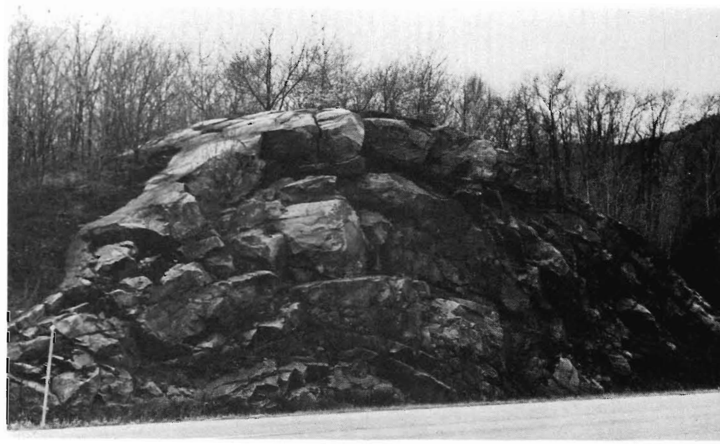


Figure 43. *Broad upfold (anticline) in gneiss, west side of Adirondack Northway (I-87) at Interchange 21, Lake George.*

Figure 44. *Tight, typical Taconic-type folds, overturned to the west with east-dipping axial planes; uppermost Hatch Hill Formation (=Schodack of Ruedemann, 1914); north side of U.S. 4, 4.5 miles northeast of Whitehall.*

wavelengths measured in a few kilometers or hundreds of meters. An exception to this are the chevron-like folds in the Glens Falls and Isle la Motte Limestones on the Tyler Farm, east of Fort Ann village (Figure 45). These tight folds, with wave lengths of 3 to 10 meters and high amplitudes, seem to be a response to thrust-slice overriding prior to complete lithification of the disturbed Middle Ordovician (Mohawkian) limestones. Whereas the lowlands carbonates are only gently folded, the lowlands shales (Snake Hill) are ubiquitously moderately to intensely folded.

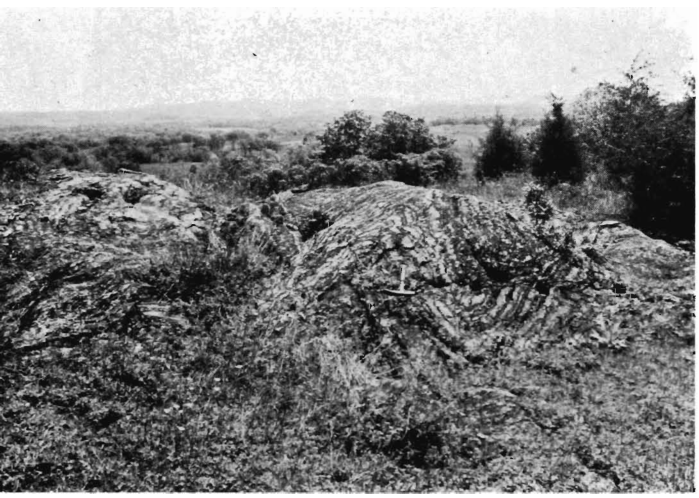


Figure 45. *Chevron-like folds in Glens Falls Limestone (looking south), Tyler Farm, 4.3 miles east-northeast of Fort Ann.*

Faults: The entire region is dissected by seven and perhaps eight fault systems (Figure 46). The principal faults have been named on the Geologic Map (Plate 1) for ease in discussion. Faults may be created by either tensional or compressional stresses. Tensional stresses cause normal and transform faults and an expansion of the crust. Compressional stresses cause reverse and strike-slip faults and a shortening of the crust. In this region, both normal and reverse faults are present and some may also possess a strike-slip component, in which horizontal movement can be demonstrated, along with vertical movement. Once fractures develop in the crust, these weak planes or zones may experience later, often repeated, adjustments.

Earliest and latest ages of faulting are difficult to ascertain. The youngest rocks (Snake Hill Shale) in the mapped area are cut by faults, hence those faults are post-Middle Ordovician. Youngest rocks involved in faulting give us a maximum age for faulting. Minimum age of faulting is delimited by determining the oldest rocks that are unaffected hence the minimum age for faulting is Pliocene (see Figure 2). The pattern of brittle fracturing within the Adirondack massif suggests that faulting was initiated in Precambrian (Late Proterozoic) time, following the compressional events of the Grenville Orogeny. Some faults offset earlier ones so that relative times of faulting can be determined.

Five fault systems were distinguished (Fisher, 1969) as relating to the Taconic Orogeny:

(1) north-south trending block faults, easterly upthrown
(2) pre-Mohawkian foreland thrusting
(3) imbricated carbonate-blocks-zone thrusting
(4) Giddings Brook Thrust
(5) east-west tear faults

Detailed mapping subsequent to 1969 has necessitated a reevaluation of this fault sequence and the times of fault initiation and reactivation. Seven or eight fault systems are now recognized (see Figure 46:)

Fault System (FS) 1 — northward thrusting, horizontal to very low angle, hard-rock thrust (Ex. Spruce Mtn. Thrust); formed during Middle Proterozoic Grenville Orogeny. No evidence of subsequent movement.

FS 2 — northeast-southwest trending, high-angle normal faults (Ex. Pine Lake Fault); formed during Late Proterozoic (Avalonian) Taphrogeny; probably reactivated several times.

FS 3 — north-south trending, high angle (normal or reverse?) faults (Ex. Pilot Knob, Copeland Pond, Welch Hollow), characterized by dominantly easterly upthrown blocks; initiated during Quebecian Taphrogeny and continued during Bonnian Phase of Taconic Orogeny; reactivated.

FS 4 — westward gravity slide faults with attendant mélange into Snake Hill mud (Ex. Giddings Brook Fault); formed during Medial Ordovician Vermontian Phase of Taconic Orogeny; no evidence of reactivation.

Figure 46

FAULT SYSTEMS
GLENS FALLS-WHITEHALL REGION, NEW YORK

EPISODE	TYPE	EXAMPLE	CRUSTAL EVENT	AGE	OTHER STRUCTURES	REGIONAL IGNEOUS ACTIVITY
FS-1 (oldest)	**Northwestward-directed** thrusting of Pharaoh Mountain charnockitic gneiss	Spruce Mountain Fault	Grenville Orogeny	*Medial Proterozoic*	healed fractures, several folding episodes, foliation	anorthosite, leucocratic granite, hornblende granite, gabbro
FS-2	**Northeast-Southwest** high-angle block faulting	Pine Lake Fault	Rensselaerian (Avalonian) Taphrogeny	*Late Proterozoic*	joints	pegmatite dikes, diabase dikes, volcanic flows
FS-3	**North-South** high-angle block faulting dominated by easterly upthrown faults, reactivation of FS-2 faults	Pilot Knob, Copeland Pond, Welch Hollow & Lake George East Faults	Taconic Orogeny, initiated during Bonnian Phase & continued into Vermontian Phase	*Early–Medial Ordovician* (Montyan-Turinian Stages)	joints, mineralized	volcanic flows volcanic ash layers
FS-4	**Westward-directed, North-South** gravity-slide faulting of slope & basin pelitic rocks into mud of proximal Snake Hill Basin	Livingston & Giddings Brook Faults	culmination of Vermontian Phase of Taconic Orogeny	*Medial Ordovician* (Canajoharie Stage)	isoclinal & kink folding, eastward-dipping axial planes, attendant mélange	volcanic ash layers
FS-5*	**Westward-directed** low-angle thrusting of carbonate shelf over itself & distal Snake Hill Basin	Comstock & Smiths Basin Faults	Hudson Valley Phase of Taconic Orogeny <u>or</u> Acadian Orogeny	*Late Ordovician* <u>or</u> *Medial–Late Devonian*	attendant subjacent chevron folding, cleavage in involved carbonates, carbonate slivers along faults	
FS-6*	**Westward-directed** low-angle thrusting of older pelitic rocks over younger, earlier emplaced ones	Rensselaer Plateau Fault	Hudson Valley Phase of Taconic Orogeny <u>or</u> Acadian Orogeny	*Late Ordovician* <u>or</u> *Medial-Late Devonian*	broad recumbent folding, cleavage imparted, carbonate slivers along faults	pegmatite veins & granite
FS-7	**North-South** high-angle block faulting, dominated by <u>westerly</u> upthrown faults, response to crustal overloading by emplaced slices & slides	Mettawee River & Lake George West Faults	"Chamhawk" Taphrogeny <u>or</u> Palisadian Taphrogeny	*Early Silurian* <u>or</u> *Late Triassic & Early Jurassic*	joints	norite or diabase
FS-8 (youngest)	**West-East to Southwest-Northeast** tear (strike-slip, in part) faulting, reactivation of FS-2 & FS-7 faults	Whitehall North, Dream Lake, Diamond Point & Sawmill Pond Faults	Palisadian Taphrogeny <u>or</u> Adirondack doming	*Late Triassic & Early Jurassic* <u>or</u> *Cenozoic*	joints	lamprophyre dikes *(Jurassic & Early Cretaceous)*

***FS-5 & FS-6 may be same fault system but involving differing rocks**

NEW YORK STATE GEOLOGICAL SURVEY

Compilation Donald W. Fisher
Graphics John B. Skiba 1/82

Figure 46. *Fault Systems, Glens Falls-Whitehall Region, New York.*

FS 5 — westward, low-angle thrusting of carbonate shelf-rock over itself with attendant subjacent chevron-like folding (Ex. Comstock & Smiths Basin Faults); formed during Hudson Valley Phase of Taconic Orogeny or during Acadian Orogeny; no evidence of reactivation.

FS 6 — westward, low-angle thrusting of slope-basin pelitic strata over earlier gravity slides with attendant recumbent folding and carbonate slivering (Ex. Rensselaer Plateau Fault); formed during Hudson Valley Phase of Taconic Orogeny or during Acadian Orogeny; no evidence of reactivation. May be the same as FS 5.

FS 7 — north-south trending, high-angle normal or reverse faulting characterized by dominant westerly upthrown blocks (Ex. Mettawee River Fault, McGregor Fault), formed during "Chamhawk Taphrogeny" or Palisadian Taphrogeny as an equilibrium response to crustal overloading by westwardly emplaced gravity slides and thrust slices; much evidence of trimming earlier thrust slices.

FS 8 — west-east trending tear faults, probably accompanying reactivation of FS 2 and FS 7 (Ex. Whitehall North, Dream Lake, Sawmill Pond, Diamond Point); formed during "Chamhawk Taphrogeny," Palisadian Taphrogeny, or perhaps as late as Adirondack doming (Cenozoic.)

The east-facing fault-line-scarp of the McGregor Fault forms a prominent wall at the western edge of the sand plain extending east to Glens Falls. This prominent normal (partly reverse) fault extends south through Saratoga Springs and along the west side of Ballston Lake. It is the most easterly of the collection of Mohawk Valley step faults. Proterozoic gneisses occur on the western, upthrown, side whereas for most of its eastern, downthrown side, the Middle Ordovician Snake Hill Shale is the surface bedrock. South of Lake George the fault parallels the Northway (I-87) and U.S. 9 on the west. North of Lake George, the dislocation continues as the Lake George West Fault. Short, north-northeast trending faults offset the main fault, creating an en echelon effect shown splendidly in parallel micro-faults (Figure 47.) Small-scale structures adjacent to some northern segments support a high-angle reverse fault movement (Isachsen and Geraghty, 1980.)

Figure 47. *Micro-faults (gash fractures) filled with calcite. The pattern probably reflects the larger one in the westerly adjacent Lake George West Fault. Ticonderoga Dolostone; on north side of access road between Interchange 22 and N.Y. 9L, north of Lake George Village.*

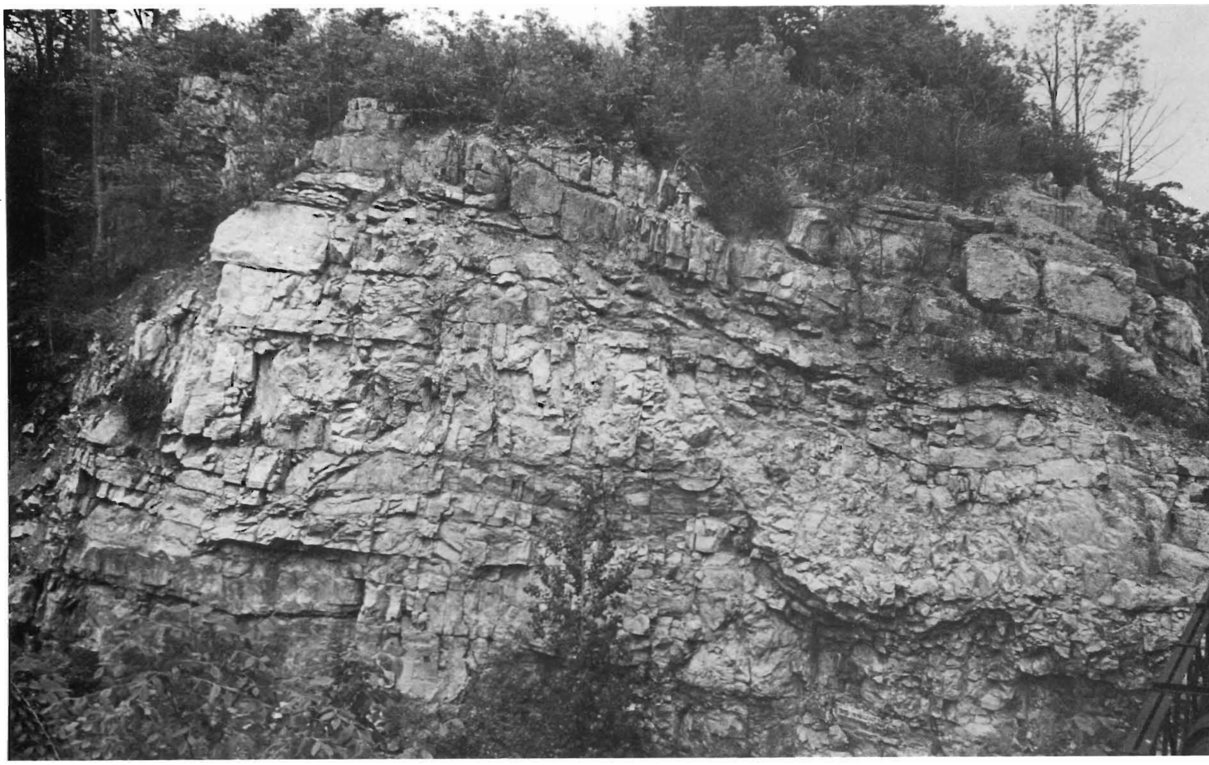


Figure 48. *Faulting within Great Meadows Formation. Along east side of Wood Creek, north of N.Y. 149.*

Scarcity of bedrock exposures in the lowland of the Glens Falls Quadrangle prohibits the identification of faults in that region. Doubtlessly other faults exist here but are hidden by the cover of glacial sediments.

In the northwest sector of the Hartford Quadrangle, the structural relations are unclear and the area around Smiths Basin is open to differing interpretations. The Smiths Basin Thrust appears to be a major one, entering the mapped region from the Fort Miller Quadrangle on the south, where Snake Hill Shale seems to occur on both sides of the fault. Noteworthy is that the topography east of the fault is somewhat more rugged. In the abandoned quarry east of Washington County 43, the older Middle Ordovician Isle la Motte Limestone is demonstrably thrust over the Middle Ordovician Snake Hill Shale. Slickensides are prevalent on the bedding planes within the limestone. In tracing the Smiths Basin Thrust north, it veers eastward along the south bank of Big Creek where disturbed Snake Hill Shale can be seen beneath the fault and imbricated Isle la Motte and Glens Falls Limestones occur above the fault plane. The Smiths Basin Thrust seemingly covers the southward trace of the Welch Hollow Fault, whose upthrown eastern side displays splendid sections of Beekmantown strata. No Beekmantown is seen south of Big Creek. Alternatively, there may be a west-east, strike-slip fault extending from west of Smiths Basin eastward up Big Creek Valley, which would account for the differing stratigraphy on both sides of Big Creek. Whichever interpretation is accepted, it seems clear that the Smiths Basin Fault (Episode FS-5) is younger than the Welch Hollow Fault (Episode FS-3.)

Another site worthy of special discussion, because of its complex and unique structural relations, is the series of outcroppings on the Tyler Farm, on the Fort Ann Quadrangle, north of Dewey Bridge Road. Here exquisite chevron-like folds (Figure 45) in the Isle la Motte and Glens Falls Limestones underly a horizontal thrust fault. This Comstock Thrust can be traced northward where the entire Beekmantown section is repeated by thrusting over itself. Relicts of Potsdam Sandstone are all that remain of the Comstock Slice, which is chopped-off on the east by the eastwardly downdropped Mettawee River Fault, in the Whitehall and Thorn Hill Quadrangles. The Comstock Thrust may be the same as the Orwell Thrust on the Benson Quadrangle in Vermont. To the south, on the Fort Ann Quadrangle, there is an outlier of the Comstock Slice southwest of the Tyler Farm. The Comstock Slice may represent an early, if not the earliest, fault of the complex Taconic thrust fault system whereby a portion of the ancient continental shelf was shoved upon itself during the westward movement of the early Taconic gravity slides. The tight folding in the subjacent limestones may have resulted from compression of incompletely lithified limestones at the time of Comstock thrusting. An alternate interpretation is that the Comstock Thrust is related to Middle Devonian Acadian thrusting and that the subjacent folding was produced at considerable depth.

On the Thorn Hill Quadrangle, between the Mettawee River Fault (normal type) on the west and the Giddings Brook Fault (gravity slide type) on the east, is a belt of truly remarkable rock. This belt displays a knobby terrane of carbonate blocks, of differing sizes, kinds, and attitudes, in a shale matrix and is a superb development of the Forbes Hill Conglomerate — a mélange of tectonic gravity-slide blocks introduced into a "syrupy" mud. This unit with some differing lithologic components and with good to poor exposure extends in front of Emmons' or Logan's Line as far south as Newburgh, N.Y. in Orange County. The mélange is thought to have been derived from spalled-off and bulldozed carbonate formations as the immense blocks of Early Cambrian through Early-Medial Ordovician strata slid westward, off the rising Green-Berkshire massif, into the deepening Late-Medial Ordovician Snake Hill Basin. East of Sciota Road, some of the carbonate blocks in the mélange are probably derived by slumping, from the *westerly* positioned carbonate shelf. Both attitude and close proximity of like formations in blocks and shelf seem more than coincidental.

Figure 49. *Providence Island Dolostone Member of the Fort Cassin Formation. Along Mettawee River, at public fishing site, 1.2 miles north northwest of N.Y. 22 – N.Y. 40 intersection – Granville Quadrangle. Note typical checkered surface of incipient joints.*

Joints — These brittle fractures, which have no movement parallel to the fracture plane, are ubiquitous in the mapped area. Joints are especially obvious in the carbonate rocks where a crude square or rhomb-shaped design is imparted by two intersecting, nearly vertical, joint sets (Figure 49). This permits easy breakup into large cubic or rhomboid blocks (Figure 50). Within argillaceous rocks joints tend to be more closely spaced and less continuous both laterally and vertically. Conjugate joints (Figure 51) have been found in proximity to known faults and have proven valuable in plotting the courses of inferred faults. No widespread mineralization has been observed along joints although localized fillings of calcite, sandstone (Figure 52), or carbonate breccia do exist. Joints enlarged by chemical solution allow larger volumes of water to migrate. At depth, joints may conceivably hold gases as well. Systematic orientation and attitude data of joints have not been collected.

Figure 50. *Joint sets in Great Meadows Formation. Active quarry, south of Underwood Road and east of Vaughn Road (Washington County 35) 3.5 miles north-northeast of Hudson Falls.*

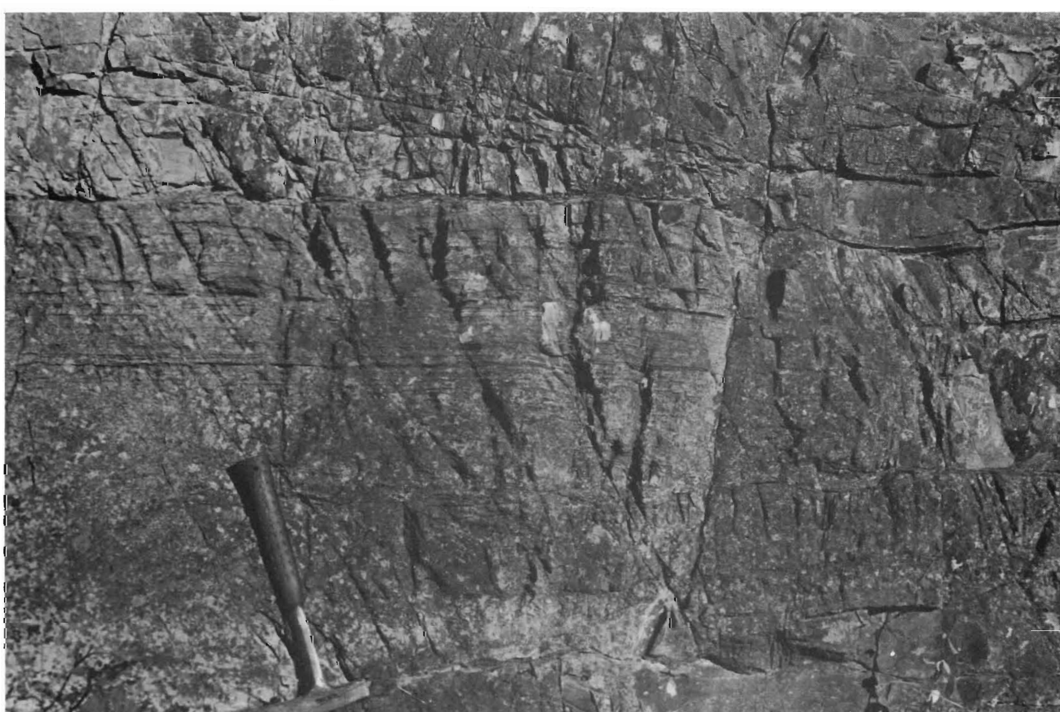


Figure 51. *Conjugate joints. Ward Siltstone Member of the Fort Cassin Formation; along east side of Washington County 10 (Sciota Rd.) near Ward Road and very close to the Mettawee River Fault.*

Figure 53. *Mettawee Argillite Member of the Nassau Formation. Along west side of Vladyka Woods Road near Hampton Hill – Thorn Hill Quadrangle. Hat rests on steep east-dipping cleavage surface; hammer rests on very gentle east-dipping bedding surface.*

Figure 52. *Ticonderoga Formation. Dolostone bed showing fracture filled with quartz-sand.*

Figure 54. *Cleavage-(dipping 70°E) bedding (dipping 30°E) relationships and imbrication of massive Isle la Motte and thin-bedded Glens Falls Limestones. Along south side of N.Y. 149, 2.2 miles east-northeast of Smiths Basin — Hartford Quadrangle.*

Cleavage — The type of very closely spaced, high angle, planar brittle fractures that permeate deformed strata and along which there has been no movement parallel to the fractures is termed cleavage. It is a sort of regional breakup of rock resulting from the release of stresses. Cleavage is most apparent in rocks that are high in clay minerals (Figure 53). When cleavage is parallel to bedding good quality slate can be extracted. When found in carbonate rocks, cleavage tends to be more irregular and less perfectly planar (Figure 54). Because regional cleavage has overprinted both the clay-rich strata of the allochthonous terrane and the carbonate strata of the autochthonous terrane it is believed that the undeformed cleavage of the mapped area was the last major structural event to have affected the Paleozoic rocks. Further south in eastern Rensselaer, Columbia, and Dutchess Counties deformed or "kink" cleavage implies that a subsequent regional deformation has crinkled the earlier cleavage, i.e., Acadian deformation has overprinted Taconic deformation. This dual deformation cannot be demonstrated within the mapped area.

ECONOMIC GEOLOGY

Feldspar — The former Ashley Quarry, near the southern tip of Putnam Mountain, about 2.5 miles west of Fort Ann, yielded large feldspar crystals known as spar that, when ground, were used in the manufacture of pottery. This site was abandoned between 1912 and 1917.

Graphite — From 1916 to 1922, the Hooper Mine, 4 miles west of Whitehall, was an important source of flake graphite. The graphite occurred in a graphitic, quartz-feldspar schist, termed the Dixon Schist (Alling, 1918, p. 71). Graphite amounted to about 5 percent of the rock, although locally the concentration reached 20 percent. Also occurring at the Hooper Mine are the subjacent Hague Gneiss and Dresden Amphibolite and the superjacent Swede Pond Quartzite; the Faxon Marble is absent. The Champlain Graphite Company Mine, about 4 miles south-southwest of Whitehall was an open pit on the east face of an abrupt cliff facing the west shore of South Bay. The operation occurred along a major fault and, displaying much fault breccia, downdropped on the southeast. Activity began in 1904 and lasted only a few years. Other prospects for graphite were the Silver Leaf Graphite Mine about a mile west of the Champlain Graphite Company Mine and also along a fault and the mine of the Adirondack (Graphite) Mining and Milling Company about 0.5 mile east of Little Diameter Hill. Both operations opened in 1904 but ceased production shortly afterward. Another graphite prospect existed about 3¼ miles northwest of Whitehall between the Delaware & Hudson Railroad and N.Y. Rte. 22.

Iron — The former Mt. Hope, Podunk, and Potter magnetite mines were situated on the west side of Putnam Mountain, west of Lake Nebo (formerly Podunk Pond), in Fort Ann Township. The workings occurred at an elevation of slightly over 900 feet in the zone mapped on the colored geologic map (Plate 1) as within the Prospect Mountain hornblende granitic gneiss. Total production at the three mines is said to have been about 350,000 tons. The ore assayed at not over 30 percent iron. It was primarily magnetite with erratic and sometimes very high amounts of pyrite; garnet, hornblende, and mica were common associated minerals. The last activity, in 1881, was at the Mt. Hope Mine when 15,000 tons were excavated and stacked. Other small prospects for magnetite have been made near The Three Ponds, 2 miles due south of Pilot Knob, and on the slope northeast of Kattskill Bay on Lake George.

Limestone (and Dolostone) — Agricultural lime has been recovered mainly from the Isle la Motte Limestone east of Smiths Basin. Cement is presently being manufactured, utilizing the Glens Falls Limestone, from rock quarried at South Glens Falls. Crushed aggregate for road beds has been quarried from the Beekmantown carbonates in the vicinity of Whitehall, north of Hudson Falls, and within Glens Falls; many small abandoned quarries in the Beekmantown Group presumably used rock for aggregate purposes. The Beekmantown and Isle la Motte (Glens Falls "Marble") carbonates were extensively used for dimension and facing stone during the late 19th and early part of the 20th centuries.

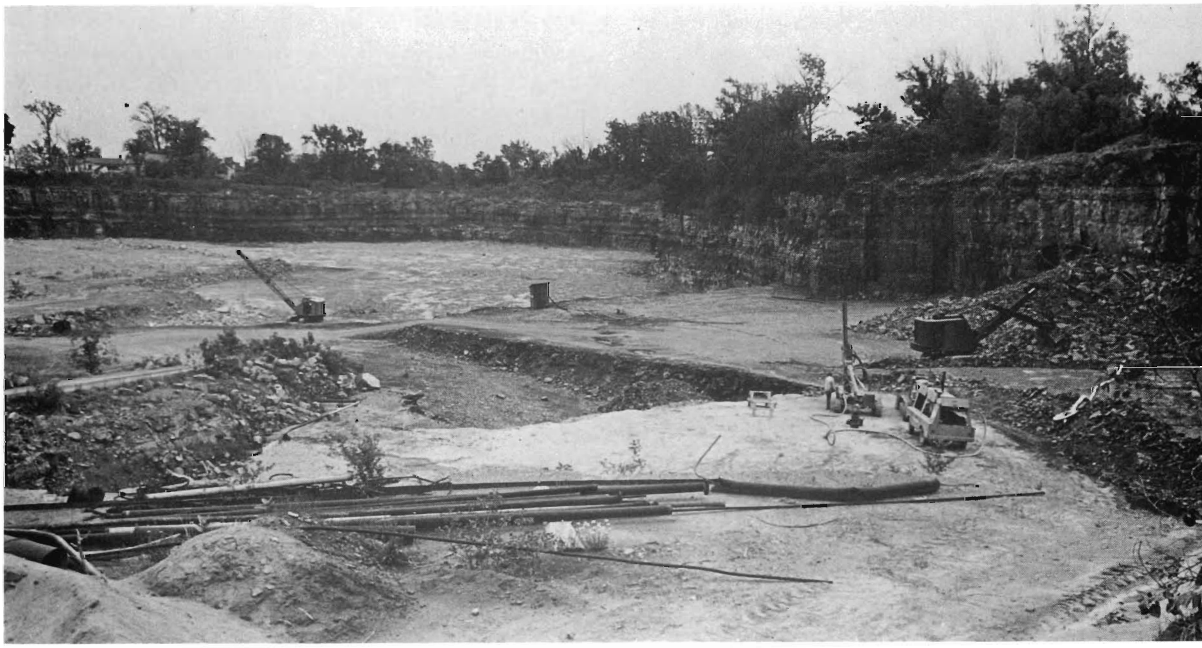


Figure 55. *Jointa Quarry (now inactive), Glens Falls between N.Y. 32 and the Hudson River; Lower Ordovician Fort Ann Formation in quarry floor with Middle Ordovician Amsterdam, Isle la Motte, and Glens Falls Limestones in quarry wall.*

Figure 56. *Potsdam Sandstone, abandoned quarry on east side of Champlain Canal, 1.3 miles north-northeast of Smiths Basin.*

Figure 57. *Close-up of loose block in above quarry showing two facies of formation – a darker gray quartzitic facies and a light gray to tan-white friable sandstone.*

Sandstone (and Quartzite) — The Potsdam Sandstone (and quartzite) was quarried for aggregate purposes in the past and also used for dimension stone in building construction (Figure 58).

Figure 58. *Private home constructed of Potsdam Sandstone dimension stone, 3.8 miles east-northeast of Fort Ann, Dewey Bridge Road.*

Rip-rap — Massive Proterozoic gneisses, Beekmantown dolostones, Potsdam Sandstone, and Austin Glen Graywacke have been used as rip-rap for holding unstable slopes and banks.

Slate — Commercial slate quarries have been opened in many formations of the Taconic Sequence. Red slate is obtained from the Indian River Formation, purple, green, and mottled purple and green slate from the Middle Granville (formerly Mettawee) Slate, black from the Browns Pond, Hatch Hill, and Mt. Merino Formations, and gray-green and brown slate from the Poultney. Although no longer sought after for roofing (except for minor amounts for repairs) slate is in demand for patios, sidewalks, and lightweight aggregate.

Sand and Gravel — Enormous amounts of sand and gravel are available from the Pleistocene sediments that mask the bedrock in the mapped area (see map of surficial deposits by Connally, 1973).

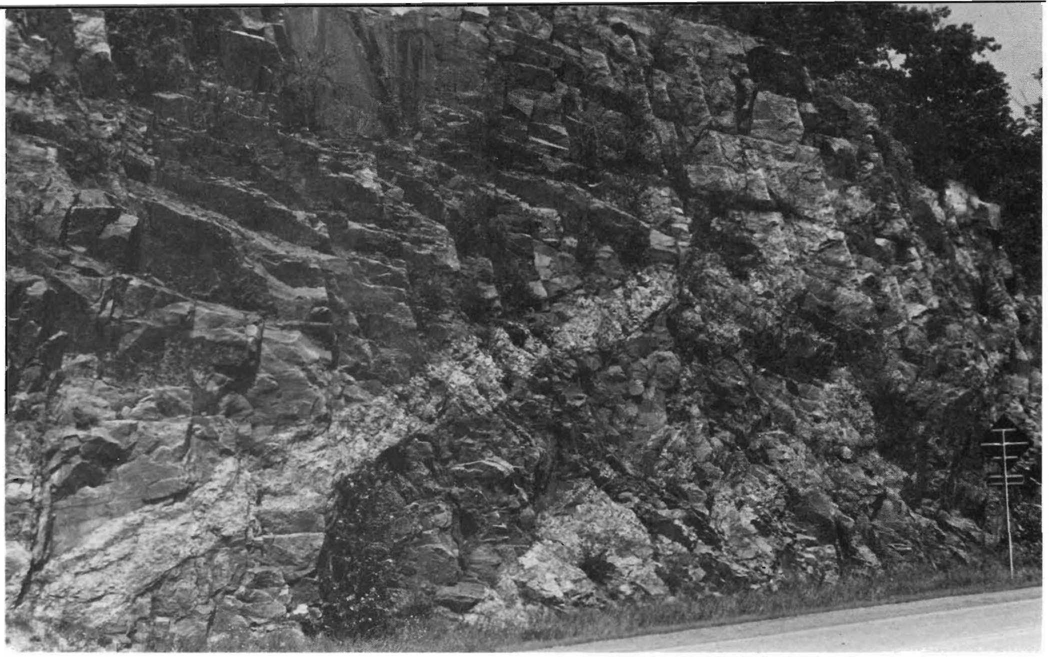


Figure 59. *Pharaoh Mountain Gneiss, cut by thin pegmatite dikes; west side of N.Y. 22, 2.7 miles north of N.Y. 22 bridge over South Bay and 0.5 mile south of Whitehall North Fault.*

Figure 60. *Closeup of dike in contact with gneiss.*

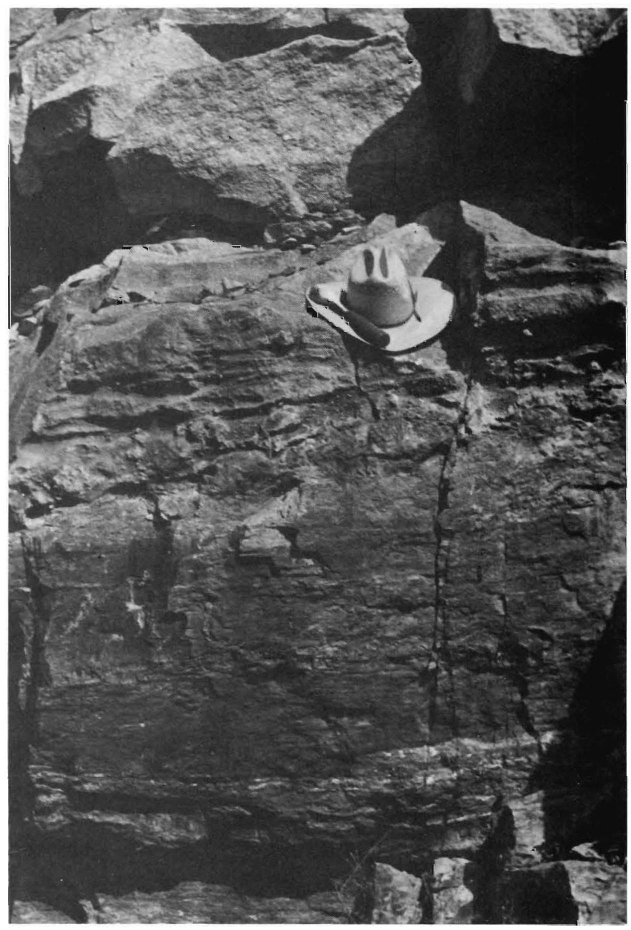


Figure 61. *Johnsburg Marble on Eagle Lake biotite-quartz-plagioclase gneiss; north side of N.Y. 22, 0.9 mile northwest of Whitehall.*

ROCK EXPOSURES: EXCEPTIONAL FOR DETAILED STUDY AND CLASS FIELD TRIPS

	a	b	c	etc.
	NW NC NE			
I	WC C EC			
	SW SC SE			
II				
III				
etc.				

Locality Code: Horizontal (letter) and vertical (Roman numeral) coordinates plus directional sector of individual quadrangle map; location plotted, by corresponding numeral on geologic map (Plate 1.)

NOTE: You must get permission from the New York State Police to park and examine rock exposures along the Adirondack Northway (I-87).

Locality #1 — Ih-NC, C, SC, (Whitehall Quadrangle). Along both sides of N.Y. 22 north of South Bay; series of extensive exposures in Pharaoh Mtn. greenish-gray charnockitic gneiss; northernmost ones, 0.5 mile south of west-east trending Whitehall North Fault, cut by thin pegmatite dikes (Figures 59, 60.) Gneiss foliation dips uniformly from 5 to 30°.

Locality #2 (private in part) — IIh-NE (Whitehall Quadrangle). Abandoned quarry north of N.Y. 22 behind highway department garage; typical section of Pharaoh Mtn. charnockitic gneiss. Along both sides of N.Y. 22, east of South Bay and northwest of Whitehall; olivine metagabbro at westernmost end of exposures, biotite-quartz-plagioclase gneiss (Eagle Lake) and thin marble (Johnsburg) striking parallel to highway and dip north (Figure 61), garnet-gneiss (Hague) nearer to Whitehall; older quartzite and biotite-quartz-plagioclase gneiss in Whitehall at curve in road.

Figure 62. *Warner Hill Limestone Member of Whitehall Formation; abandoned quarry on north side of Washington County 10, 2 miles northeast of Whitehall.*

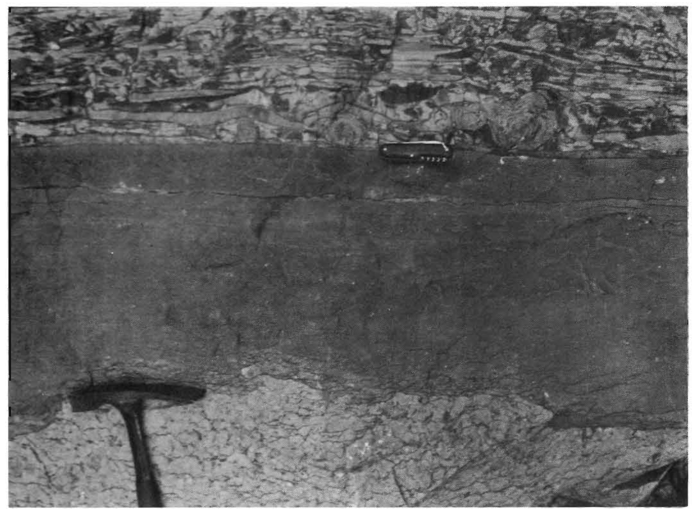
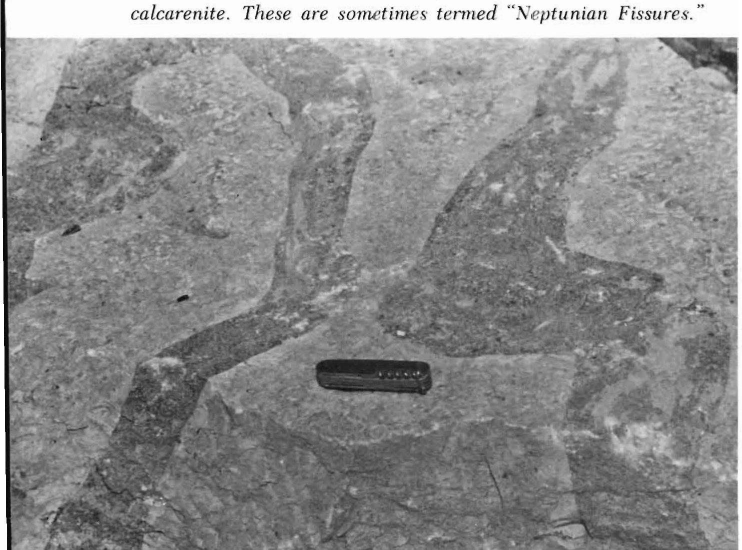


Figure 63. *Close-up of three facies of Warner Hill Limestone at above locality; darker gray calcarenite on lighter gray micrite (at hammer head), slab breccia with small* Cryptozoon *heads (near knife).*

Figure 64. *Same locality; large stromatolite.*

Figure 65. *Winchell Creek Siltstone and Kingsbury Limestone Members of the Great Meadows Formation. Inactive quarry east of Norton Rd. and north of U.S. 4, 2.1 miles east of Whitehall.*

Figure 66. *Kingsbury Limestone; same locality. Closeup of darker gray calcarenite fillings in lighter gray calcilutite (micrite) limestone, demonstrating chemical solution of micrite with voids filled later by calcarenite. These are sometimes termed "Neptunian Fissures."*



Locality #3 (private) IIi-NE (Whitehall Quadrangle). Inactive quarry (Figure 62) along north side of Washington County 10, 1.5 miles northeast of Whitehall. Shows four differing dolomitic limestones in Warner Hill Member of Whitehall Formation (Figure 63, 64): algal stromatolites; oolitic calcarenite; micrite; slab breccia. Some significant, but rare, trilobites have been found.

Locality #4 (private) IIi-SE (Whitehall Quadrangle). Inactive quarry (Figure 65) on north side of U.S. 4 and east of Norton Road; relatively sharp contact between Winchell Creek Siltstone and Kingsbury Limestone members of the Great Meadows Formation. Note especially the trace fossils, cross-lamination, and crossbedding in the Winchell Creek and the darker gray coarser limestone fillings in the light gray weathering micritic dolomitic limestone (Figure 66); algal structures.

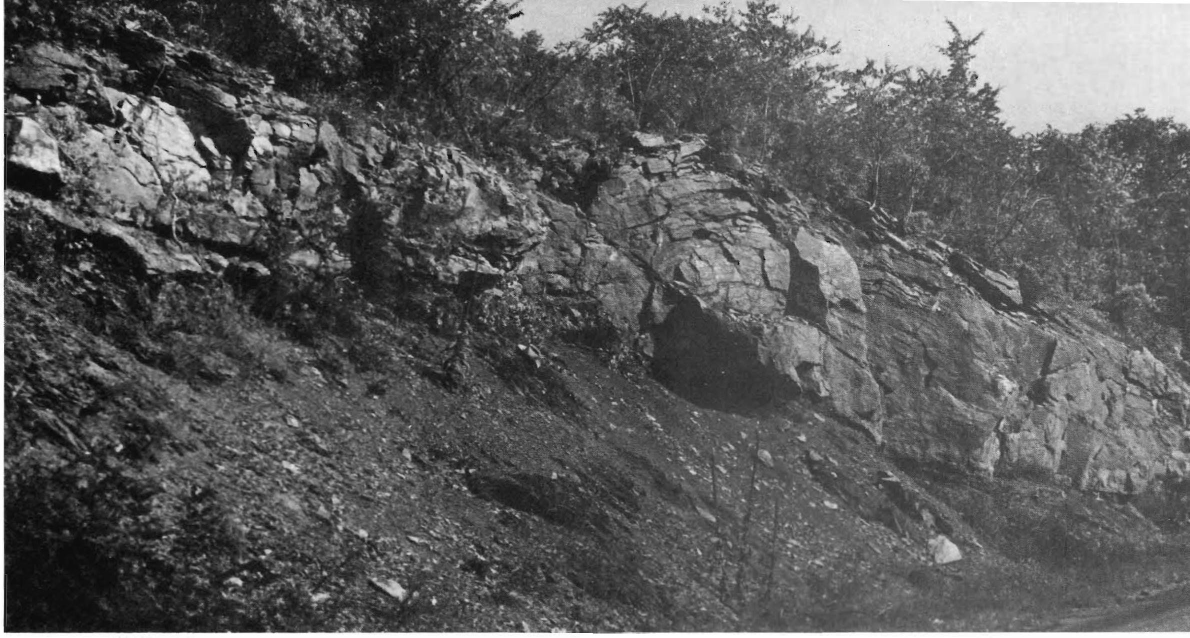


Figure 67. *Block of Isle la Motte Limestone resting abruptly on Snake Hill mudstone comprising the Forbes Hill Conglomerate; along north side of Washington County 11 near Westcott Rd.*

Figure 68. *"Window" through Giddings Brook Slide, exposing block of carbonate in mélange; behind William Miller Chapel on Washington County 11, southeast of Hampton Hill.*

Figure 69. *Close-up of "window" rock.*

Locality #5 — Ij-SE (Thorn Hill Quadrangle). Along Washington County 11 (Figure 67) and along Wescott Road, exposures of carbonate blocks, of differing formations with differing attitudes, in shale; this is the Forbes Hill Conglomerate, a mélange derived from the westward emplacement of pelitic-rock bearing gravity slides over shelf carbonates. This type of tectono-sedimentary deposit is unique to the Taconic area.

Locality #6 (private) — Ik-SC (Thorn Hill Quadrangle). South of Washington County 11, 0.4 mi. ESE of Hampton Hill, few meters south of William Miller Chapel; "window" in Giddings Brook gravity slide, exposing underlying carbonate block (Fort Cassin Formation ?) within mélange (Figures 68, 69) surrounded by Bomoseen Member of Nassau Formation.

Locality #7 — IIk-C (Thorn Hill Quadrangle). Along north side of U.S. 4, about midway between Whitehall, N.Y. and Fairhaven, Vt.; very limited parking and narrow shoulders as well as heavy traffic; superb exposure of westwardly overturned folds and small thrust faults in interlayered thin-bedded limestones and gray-black shales (Figure 70); uppermost part of Hatch Hill Formation, **No hammering or chiseling on this outcrop-examination and photography only!**

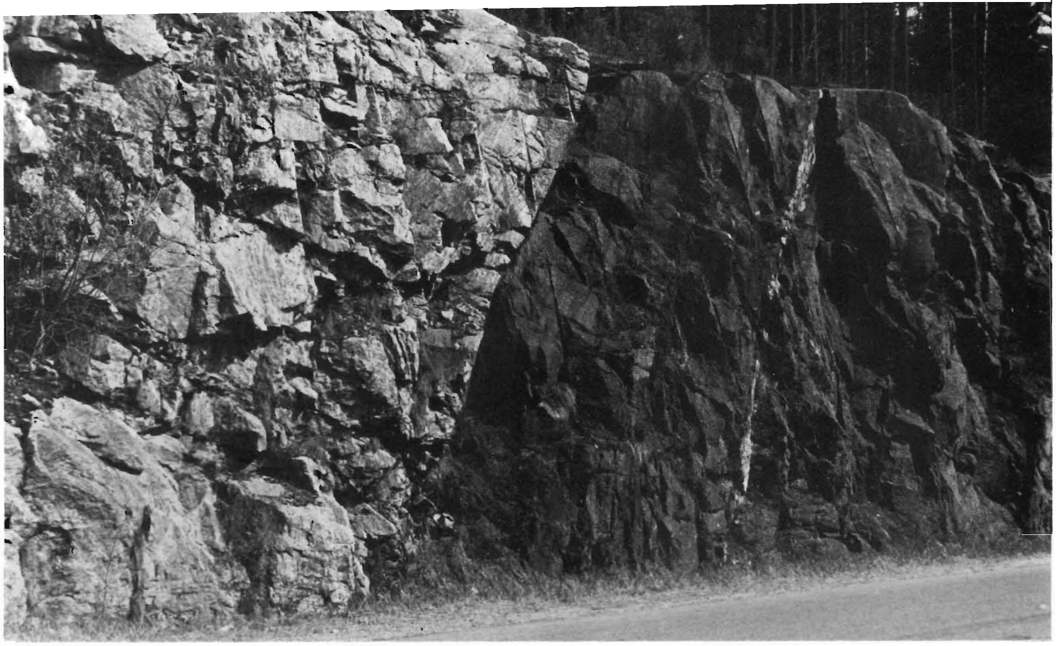
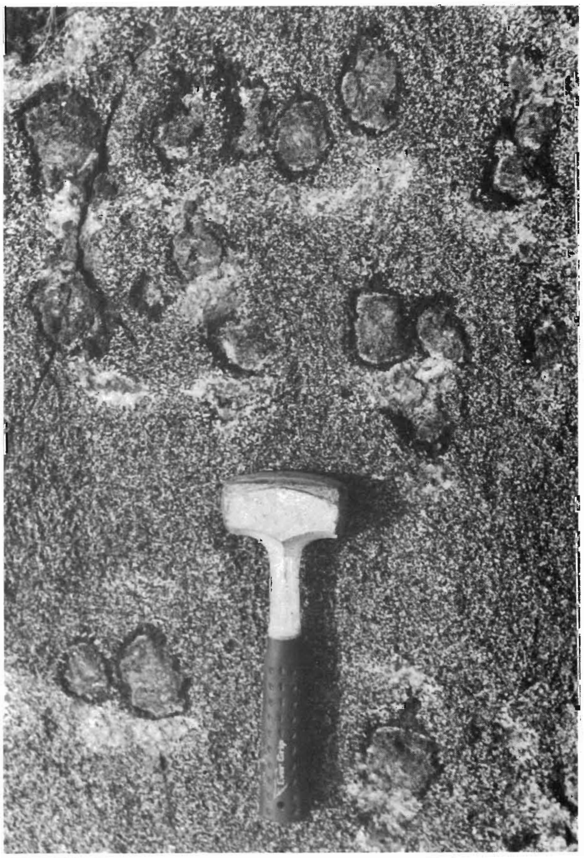


Figure 71. *Abrupt contact between Prospect Mtn. granitic gneiss (hgg) on left and mafic granulite (mag) on right; east side of Wall St. 4.8 miles north-northwest of Interchange 22, Lake George.*

Figure 72. *Across Wall St. on west side is close-up of garnets, with hornblende aureoles, in mafic granulite.*



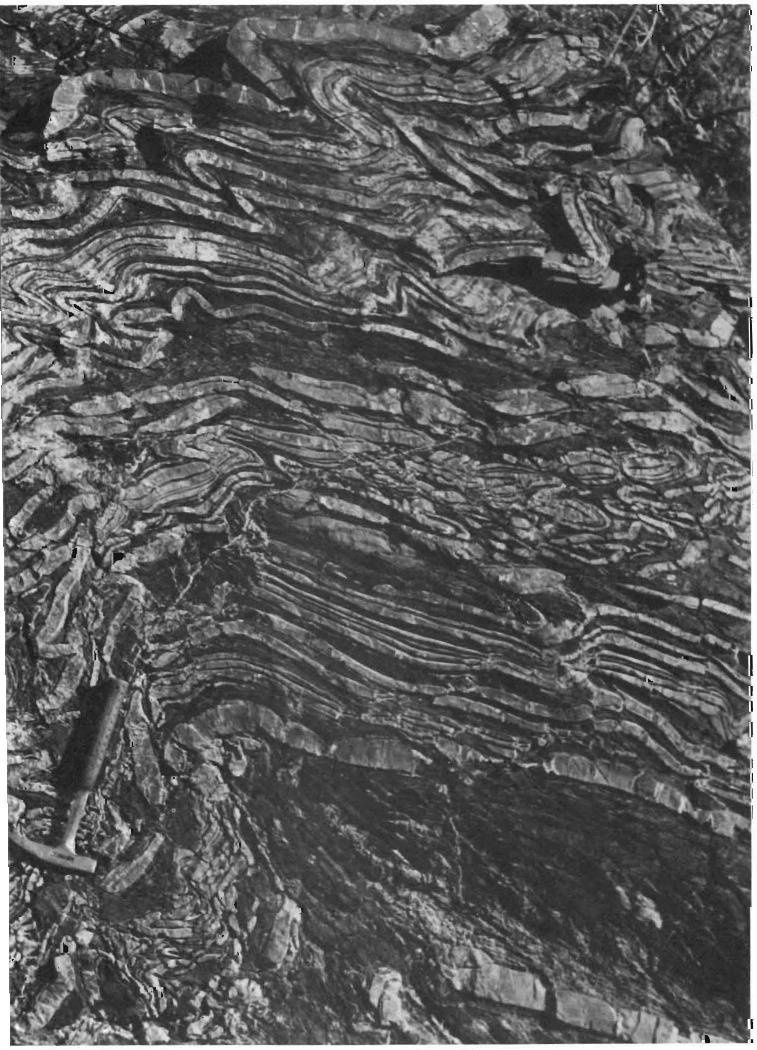


Figure 70. *Folded limestones and interbedded shales in uppermost Hatch Hill Formation (= Schodack of Ruedemann, 1914): north side of U.S. 4, 3.5 miles east of Whitehall.*

Locality #8 IIIj-NE (Thorn Hill Quadrangle). Along northern extremity of Beckett Road near its intersection with N.Y. 273, on north side of bend; interesting tectonic block within the Forbes Hill Conglomerate; overturned and dipping 55°E, containing, from west to east, Snake Hill Shale, Glens Falls Limestone, Isle la Motte Limestone, and Providence Island Dolostone. This is doubly significant in that the lithified Snake Hill Shale forms part of the block, thereby demonstrating that uppripping of shelf and emplacement occurred after the basal Snake Hill had been deposited.

Locality #9 Iva-NW (Lake George Quadrangle). In extreme northwest corner of the quadrangle, along Wall St. (paralleling I-87); on east side of road is an abrupt contact of garnet-rich gabbro (mag) with Prospect Mtn. hornblende granitic gneiss (hgg) (Figure 71); on west side of road is good exposure of large garnets with hornblende aureoles in gabbro matrix (Figure 72). Three miles north of here is a faulted outlier of upper Beekmantown strata in the southbound lane and median of Interstate 87.

Locality #10 Va-SW (Lake George Quadrangle). Prospect Mountain Memorial Highway; this is the type locality for the Prospect Mtn. granitic gneiss (hgg), many superb outcrops (hgg) with several plug-like intrusions of dark gray to black olivine metagabbro (omg); excellent view of Lake George graben at second parking overlook from bottom; some granitic gneiss has coarse pegmatitic phase (near summit of mountain.) **Park cars only at designated areas.**

Locality #11 Vb-NC (Lake George Quadrangle). Hearthstone State Campsite, 2 miles north-northeast of Lake George Village between N.Y. 9N and Lake George; eastward dipping ripple-marked Potsdam Sandstone (Figure 73) at lake edge resting unconformably upon Prospect Mtn. granitic gneiss. **No hammers to be used in State Campsite.**

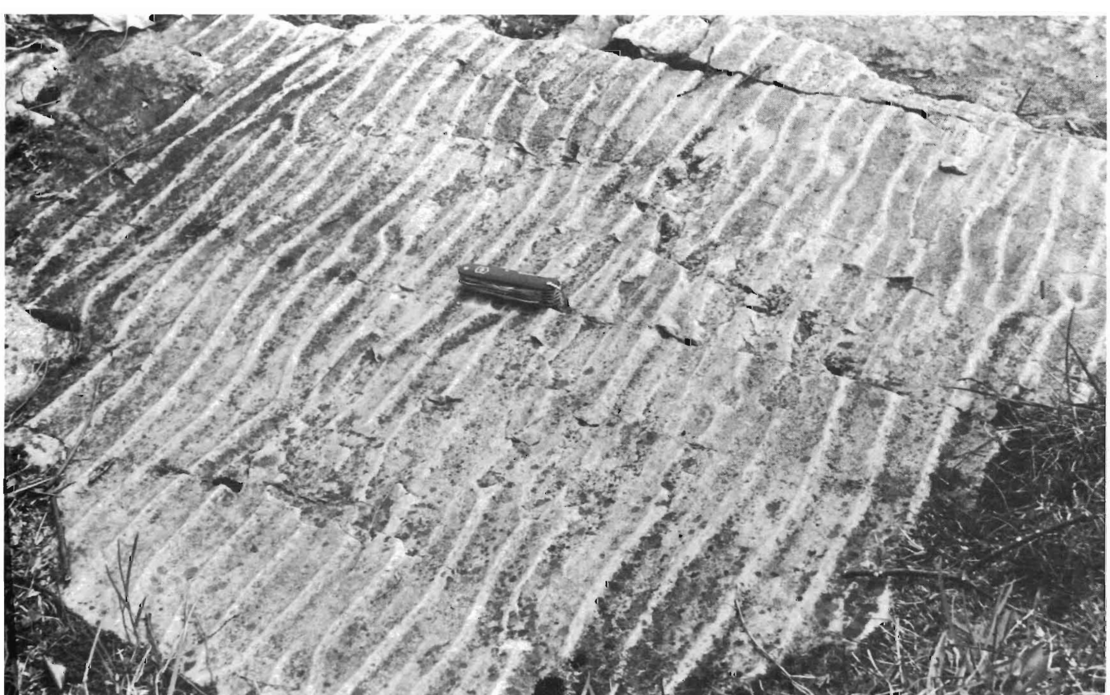


Figure 73. *Ripple-marked Potsdam Sandstone near shore of Lake George, Hearthstone Point Campsite, 2 miles northeast of Interchange 22, Lake George.*

Figure 74. *Limestone and dolostone in Whitehall Formation. Along abandoned Delaware and Hudson Railroad bed (now a paved bikeway) in Lake George Battleground Park; Lake George in right background; Prospect Mountain in rear.*

Figure 75. *Contact of Late Cambrian Potsdam Sandstone, dipping 8°E, unconformably upon Hague Gneiss, dipping 25°ESE; road intersection with U.S. 4, 1.7 miles northeast of Fort Ann.*

Figure 76. *Close-up of Potsdam Sandstone at above exposure. Note that quartz pebbles (above knife) are not basal.*

Locality #12 VIb-NW (Lake George Quadrangle). Lake George Battlefield Park; exposures of Whitehall Formation (limestone and dolostone) in ridge east of Fort George Road (Figure 74); carbonate blocks used in making fortifications. **No hammers to be used in State Park.**

Locality #13 Vg-EC (Fort Ann Quadrangle). Along east side of U.S. 4 where access road goes east over old roadbed toward railroad; contact of Late Cambrian Potsdam Sandstone (Ep), dipping 8°E, unconformably on Proterozoic Hague Gneiss (ag_1), dipping 25°E (Figure 75.) Note quartz pebbles in lower 1.5 feet (but not at base) of Potsdam (Figure 76) and orange-brown staining of soil along unconformity.

Locality #14 IVh-C (Fort Ann Quadrangle). Several excellent exposures of Hague garnet-gneiss (ag_1), some with inclusions of olivine metagabbro (omg), along both sides of U.S. 4 extending north 3.7 miles from Locality #13 (Figure 77); most northerly of this sequence (on west side of road) is where the Bryant Lake Marble (m_2) rests on the Hague and is cut by a vertical diabase dike (Figure 78); marble has inclusions of a diabase-like rock.

Locality #15 (private) Vh-WC (Fort Ann Quadrangle). Two miles east of Dewey Bridge on north side of Dewey Bridge Road, on Tyler Farm; chevron folds (Figure 45) in Glens Falls and Isle la Motte Limestones beneath the Comstock Thrust slice with gently dipping Beekmantown units (Whitehall, Great Meadows, Fort Ann Formations); much calcite filling of joints, especially in Isle la Motte Limestone.

Figure 77. *Close-up of Hague Gneiss showing inclusion, east side of U.S. 4, across road from Figure 78.*

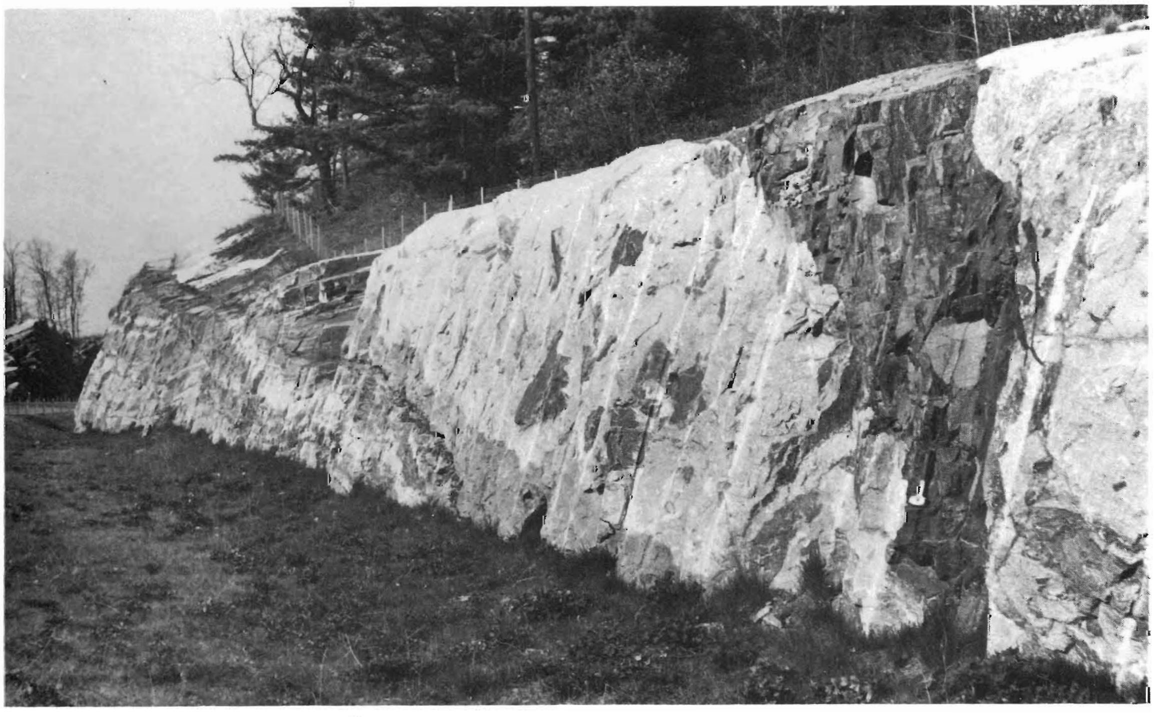


Figure 78. *Bryant Lake Marble on Hague Gneiss, both cut by diabase dike, west side of U.S. 4, 1.5 miles north of intersection of U.S. 4 and N.Y. 22 at Comstock. Note inclusions within marble.*

Figure 79. *Trace of Mettawee River Fault along Mettawee River, public fishing spot, 1.2 miles north of N.Y. 22 – N.Y. 40 intersection.*

Locality #16 IVj-WC (Granville Quadrangle). Along the Mettawee River at public fishing site, 1.3 miles north of N.Y. 40 intersection with N.Y. 22; uppermost Beekmantown Providence Island Dolostone (Figure 79), dipping east, upthrown along Mettawee River Fault, with Middle Ordovician Snake Hill Shale in river and along east bank; Middle Ordovician limestones have been faulted out of this section.

Locality #17 (private in part) VIj-WC (Granville Quadrangle). Along east side of N.Y. 40 near Warren Road at base of Taconic Uplands; uniformly southeastward-dipping Austin Glen Graywacke, with shale interbeds (Figure 80); interpreted as a separate gravity slide older than the Giddings Brook Slide or as a large tectonic block within the Forbes Hill Conglomerate. Emerald Hill, on the farm of the same name, 0.5 mile west and north of Warren Road is a large dolostone block in the Forbes Hill Conglomerate.

Figure 80. *Austin Glen graywacke and shale; east side of N.Y. 40, 2.75 miles northeast of Hartford, near intersection with Warren Road.*

Locality #18 (private) VIIIc-EC (Glens Falls Quadrangle). Abandoned Jointa Quarry between N.Y. 32 on the north and the feeder canal on the Hudson River, displays Beekmantown Fort Ann Formation in floor and Middle Ordovician Amsterdam, Isle la Motte, and Glens Falls Limestones in quarry walls (Figure 55); fossil collecting good with brachiopods and mollusks most abundant.

Locality #19 (private) VIIId-SW (Hudson Falls Quadrangle). Active cement quarry at east end of South Glens Falls between Ferry Boulevard on the south and Hudson River on the north; large exposure (Figure 81) of Glens Falls Limestone, with abundant fossils (chiefly brachiopods, bryozoans, trilobites) abruptly overlain by calcareous mudstone of the lower Snake Hill Formation. **Permission needed to enter this quarry.**

Locality #20 VIIIe-EC (Hudson Falls Quadrangle). Along Bond Creek, where Washington County 41 crosses it, 2 miles northeast of Hudson Falls. Splendid fossil collecting uppermost Glens Falls Limestone; brachiopods, bryozoans, trilobites, and crinoid stems are especially common.

Locality #21 (private) VIIg-WC (Hartford Quadrangle). Abandoned quarry (Figure 82) east of Washington County 43, ¾ mile southeast of Smiths Basin; Isle la Motte Limestone thrust over Snake Hill Shale (actual fault shown along old narrow access road to quarry); splendid slickensides (Figure 83) along bedding planes in Isle la Motte Limestone with some calcite veins. The Smiths Basin Thrust can be followed eastward along Big Creek where imbricated Isle la Motte and Glens Falls Limestones are repeated with disrupted Snake Hill Shale beneath.

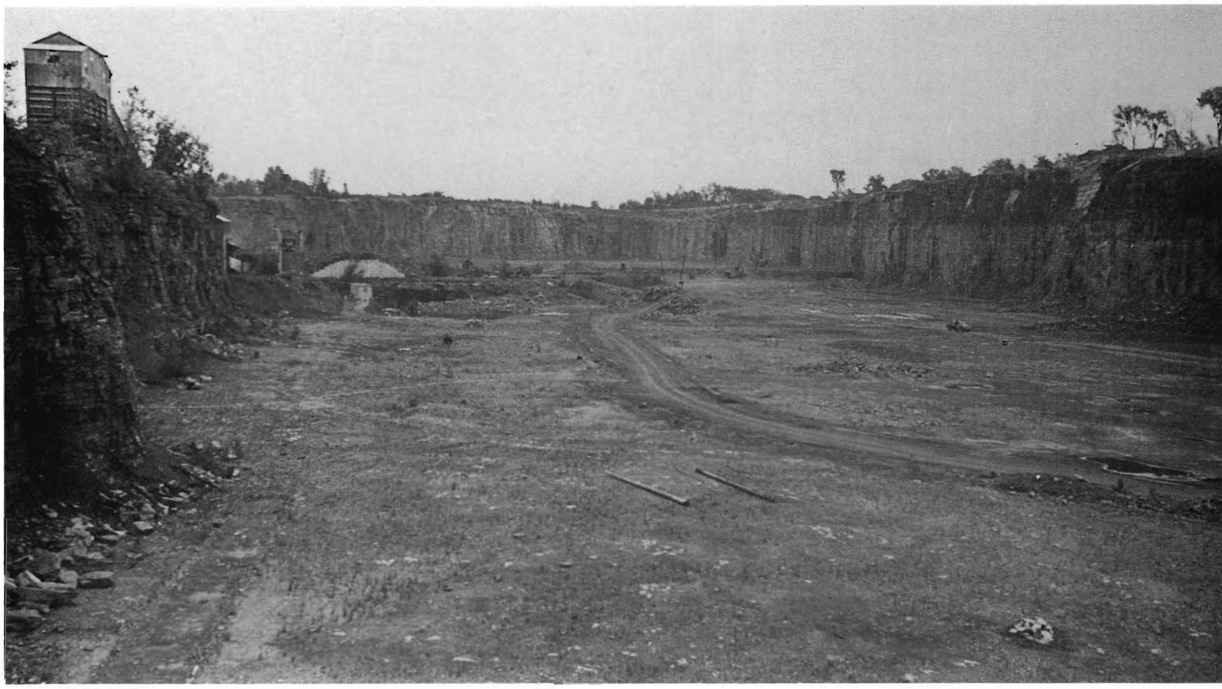


Figure 81. *Active quarry at east end of South Glens Falls; Glens Falls Limestone sharply overlain, on south wall, by calcareous mudstone of basal Snake Hill Formation.*

Figure 82. *Abandoned quarry, Isle la Motte Limestone, dipping east, along Smiths Basin Fault. Dip slope on Proterozoic gneisses of Putnam Mountain in left background; Battle Hill seen beyond limestone ledge.*

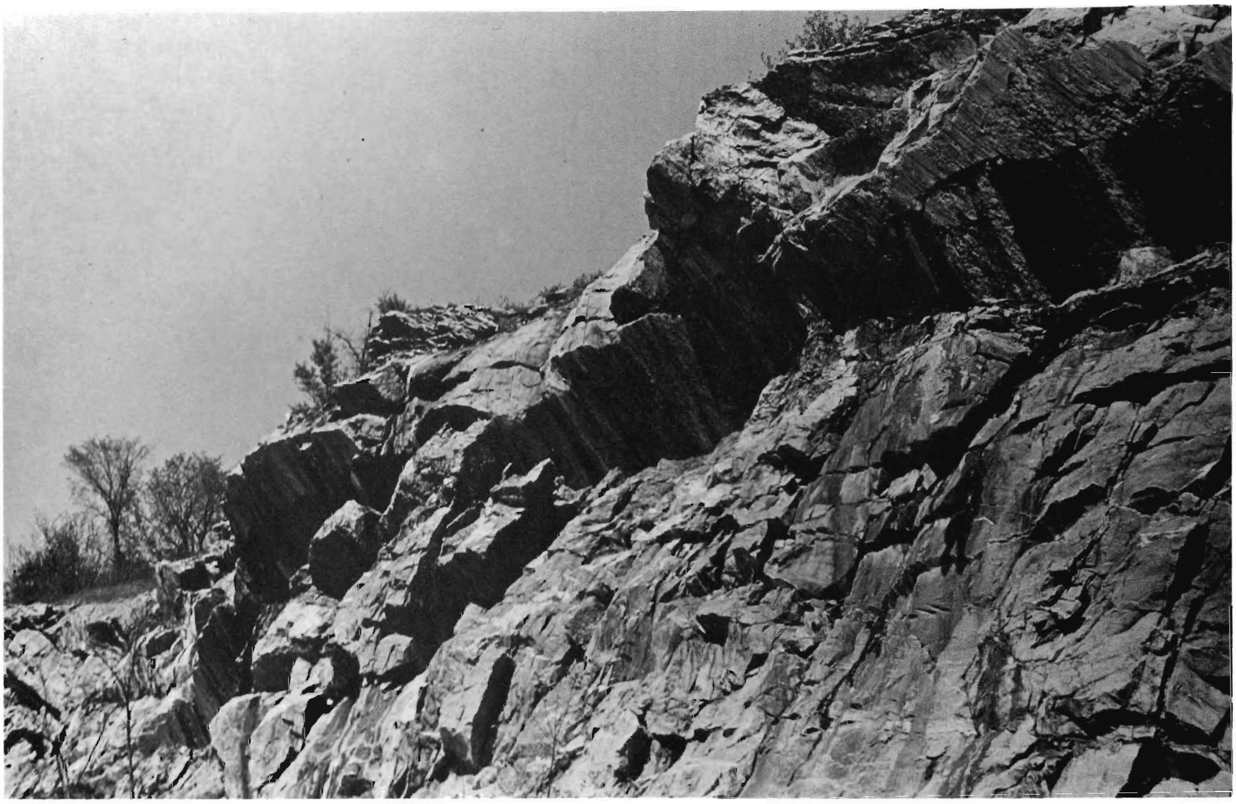


Figure 83. *Slickensides along bedding planes in Isle la Motte Limestone, abandoned quarry ¾ mile southeast of Smiths Basin.*

Figure 84. *Fort Edward Dolostone Member of Great Meadows Formation. Note great concentration of scoriaceous chert, termed by archeologists "Fort Ann Flint."*

Locality #22 (private) VIIg-NC (Hartford Quadrangle). Field exposures, especially on north of N.Y. 149, east of Smiths Basin on former Bushlea Farm, beginning along east side of Champlain Canal in abandoned quarry of Potsdam Sandstone (Figure 56) and extending eastward through Ticonderoga, Whitehall, Great Meadows and Fort Ann Formations. Great section to study differing limestone-dolostone types. Also, good trace fossils and cross-lamination and cross bedding in Winchell Creek Siltstone, scoriaceous (Figure 84) chert and algal "biscuits" (Figure 85) in Fort Edward Dolostone and breccia-filled solution cavities (Figure 31) in Smiths Basin Member of Great Meadows Formation. Scarce gastropods and nautiloids are found in Whitehall, Great Meadows, and Fort Ann formations, with very rare trilobites and conodonts; especially good specimens of the gastropod *Lecanospira* (Figure 86) occur in the Fort Ann Formation.

Figure 85. *Fort Edward Dolostone Member of the Great Meadows Formation. Field exposures north of N.Y. 149 on former Bushlea Farm. Note algal biscuits in mottled calcitic dolostone.*

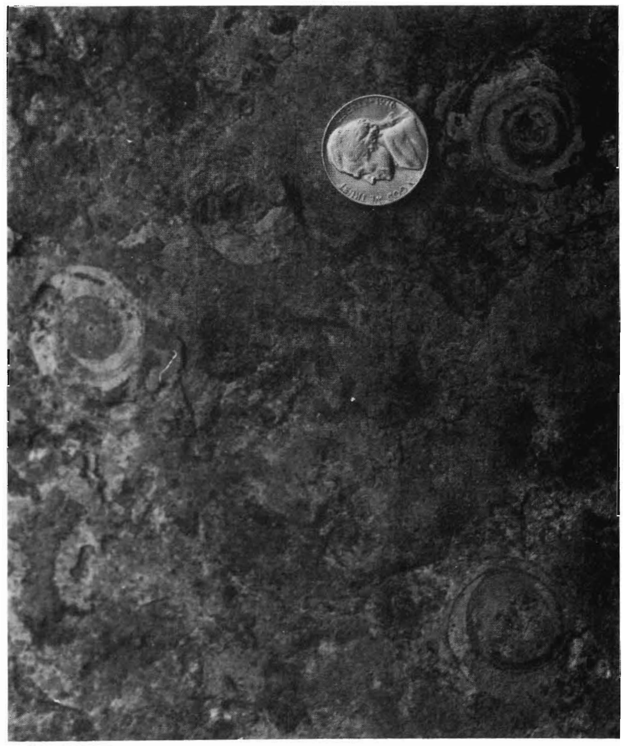


Figure 86. *Close-up of bedding plane surface of Fort Ann Formation showing mottled dolomitic limestone with dolomite weathering in relief. Bushlea Farm, east of Smiths Basin. Note the gastropod* Lecanospira *– an index fossil to the Middle Canadian (Roubidouxan).*

Locality #23 VIIg-NE (Hartford Quadrangle). Two miles east-northeast of Smiths Basin along south side of N.Y. 149 (Figure 87); contact of thinner-bedded, dark gray weathering Glens Falls Limestone on massive, light gray weathering Isle la Motte Limestone; good display of eastward-dipping bedding-cleavage relationships with bedding dipping 35–40° and cleavage dipping 65–75° (Figure 54.)

Figure 87. *Along south side of N.Y. 149, 2.2 miles east-northeast of Smiths Basin; contact (at collecting bag) of Glens Falls Limestone (on left) resting on Isle la Motte Limestone (on right).*

Figure 88. *Limestone conglomerate block within Forbes Hill Conglomerate; southeast of North Argyle along Tripp Road and west of Todd Mtn.*

Locality #24 IXg-NW (Hartford Quadrangle). Along both sides of Mahaffey Road, 5 miles east of Fort Edward, many exposures of cleaved Snake Hill Shale; note brown weathering of these shales in this more rugged terrane compared to appearance of Snake Hill Shale in lowlands terrane, for example, at Bakers Falls on the Hudson River.

Locality #25 (private in part) IXg-SE (Hartford Quadrangle). North and south of Tripp Road, 0.7 mile southeast of North Argyle, between N.Y. 40 on west and Todd Mountain on the east; blocks of Balmville? limestone conglomerate (Figure 88) within the Forbes Hill Conglomerate, scarce fossils equate with Glens Falls Limestone; this mélange is associated with the Giddings Brook gravity thrust fault at the base of Todd Mountain. Looking west, note splendid skyline view of Adirondack Uplands across the Hudson-Champlain Lowlands.

PROBLEMS REMAINING

During the course of mapping, a number of questions and problems arose and some of these remain unresolved and would form topics for future studies. These may be conveniently divided into: **paleontologic studies, petrologic studies, structural studies, economic studies.**

Paleontologic Studies

(1) Conodont zonation of Beekmantown, Black River, and Trenton carbonate rocks toward more precise correlation
(2) Megafauna of the Fort Cassin Formation, specifically of the Sciota Limestone
(3) Investigation and description of the Early Cambrian non-trilobite fauna, customarily classed as *Incertae sedis*
(4) Search for additional graptolites in the Snake Hill, Austin Glen, Mount Merino, Indian River and Poultney Formations

Petrologic Studies

(1) Petrology and sedimentology of Potsdam Sandstone
(2) Petrology and sedimentology of Fort Cassin Formation
(3) Petrology and sedimentology of quartzites and conglomerates in the Taconic Sequence

Structural Studies

(1) Smaller fold orientations and relative ages
(2) Distribution of intensity of folding and furthest westward extent
(3) Are there two periods of cleavage formation? How far west can cleavage be identified?
(4) Joint Sets, their trends and dips

Economic Studies

(1) Oil and gas possibilities in the region
(2) Potential for crushed rock and building stone
(3) Uses for slate refuse
(4) Water sources and possibilities for contamination
(5) Landfill locations and industrial waste disposal

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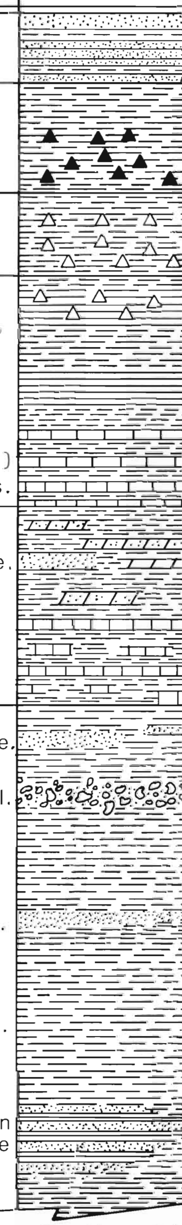
Figure 89

ROCK SECTION
(Taconic Sequence)
GLENS FALLS-WHITEHALL REGION, N.Y.

AGE		GROUP	FORMATION	MEMBER	LITHOLOGY	THICKNESS (feet)
ORDOVICIAN	Medial	NORMANSKILL	Austin Glen gywk., gray sh.			0-350
ORDOVICIAN	Medial	NORMANSKILL	Mount Merino black shale, slate; black chert			300-500
ORDOVICIAN	Medial	NORMANSKILL	Indian River red, green sh., sl.; red, green cht.			70-200
ORDOVICIAN	Early		Poultney	C, B: Owl Kill argillite, gray-green sl., cht.		650-750
ORDOVICIAN	Early		Poultney	A Schaghticoke (=White Creek) black sh., ribbon ls.		75-100
CAMBRIAN	Late		Hatch Hill gray, black shale, quartzite, dolostone	including Eagle Bridge Qtzte.		0-25; 250-300
CAMBRIAN	Med.		West Castleton (Schodack) gray-black sh.,ls., congl.			250-350
CAMBRIAN	Early		Nassau	Mudd Pond tan qtzte.		0-12
CAMBRIAN	Early		Nassau	Castleton Congl.		0-8
CAMBRIAN	Early		Nassau	Zion Hill green qtzte.		5-20
CAMBRIAN	Early		Nassau	Mettawee green, purple sh., sl.		
CAMBRIAN	Early		Nassau	Bomoseen green gywk., argillite		300-600
						Nassau total: 1,500-2,000



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Fault contact with younger Medial Ordovician Snake Hill Shale (see Figure)

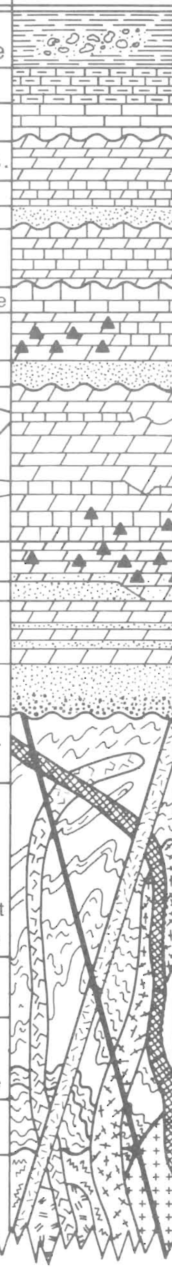
Cht. Chert Congl. Conglomerate Gywk. Graywacke Ls. Limestone Qtzte. Quartzite Sh. Shale Sl. Slate

Figure 89. *Rock Section (Taconic Sequence) Glens Falls – Whitehall Region, N.Y.*

Figure 90

ROCK SECTION
(exclusive of Taconic Sequence)
GLENS FALLS-WHITEHALL REGION, N.Y.

AGE	GROUP	FORMATION	MEMBER	LITHOLOGY	THICKNESS (feet)
ORDOVICIAN, Medial		Snake Hill Shale	incl. Forbes Hill megaconglomerate		1,300+
ORDOVICIAN, Medial	TRENTON	Glens Falls Ls.			70-115
ORDOVICIAN, Medial	BLACK RIVER	Amsterdam Ls			0-6
ORDOVICIAN, Medial	BLACK RIVER	Isle la Motte			0-65
ORDOVICIAN, Early	BEEKMANTOWN	Fort Cassin	Providence Island Ds.		0-190
ORDOVICIAN, Early	BEEKMANTOWN	Fort Cassin	Sciota Limestone		26-135
ORDOVICIAN, Early	BEEKMANTOWN	Fort Cassin	Ward Siltstone		0-39
ORDOVICIAN, Early	BEEKMANTOWN	Fort Ann ls., ds.			50-115
ORDOVICIAN, Early	BEEKMANTOWN	Great Meadows	Smith Basin Limestone		0-25
ORDOVICIAN, Early	BEEKMANTOWN	Great Meadows	Fort Edward Ds.		60-150
ORDOVICIAN, Early	BEEKMANTOWN	Great Meadows	Winchell Creek Sts.		8-110
ORDOVICIAN, Early	BEEKMANTOWN	Whitehall	Rathbunville School Limestone		0-11
ORDOVICIAN, Early / CAMBRIAN, Late	BEEKMANTOWN	Whitehall	Skene Dolostone		60-164
CAMBRIAN, Late	BEEKMANTOWN	Whitehall	Steve's Farm Ls.		0-20
CAMBRIAN, Late	BEEKMANTOWN	Whitehall	Warner Hill Limestone		5-82
CAMBRIAN, Late	BEEKMANTOWN	Whitehall	Finch Dolostone		46-85
CAMBRIAN, Late	BEEKMANTOWN	Whitehall	Mosherville Ss.		
CAMBRIAN, Late	BEEKMANTOWN	Ticonderoga ds., ss.			150-240
CAMBRIAN, Late		Potsdam Sandstone	Keeseville		85-255
*PROTEROZOIC	LAKE GEORGE	Thunderbolt Mountain	including Beach Mt. Amphibolite		sedimentary thickness unknown due to intense deformation
*PROTEROZOIC	LAKE GEORGE	Springhill Pond	Bear Pond Schist Catamount Schist Bryant Lake Marble Swede Pond Quartzite Dixon Graphite Schist Hague Garnet Gneiss		
*PROTEROZOIC	LAKE GEORGE	Treadway Mountain Biotite Gneiss			
*PROTEROZOIC	LAKE GEORGE	Paradox Lake	Dresden Amphibolite Johnsburg Marble Sacandaga Quartzite		
*PROTEROZOIC	LAKE GEORGE	Eagle Lake Biotite Gneiss			
*PROTEROZOIC	PISECO LAKE	Brant Lake Gneiss✱			
*PROTEROZOIC	PISECO LAKE	Pharaoh Mountain Charnockitic Gneiss			



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*All Proterozoic sedimentary rocks are penetrated by Marcy Anorthosite, Trumbull volcanics, Prospect Mtn. Granite, olivine gabbro, then metamorphosed and followed by intrusion of pegmatite dikes and lastly diabase dikes.

✱ not certainly identified in this region

Ds. Dolostone Ls. Limestone
Ss. Sandstone Sts. Siltstone

Figure 90. *Rock Section (exclusive of Taconic Sequence) Glens Falls – Whitehall Region, N.Y.*

THE NEW YORK STATE EDUCATION DEPARTMENT

STATE SCIENCE SERVICE
Richard H. Monheimer, Director

GEOLOGICAL SURVEY
Robert H. Fakundiny, State Geologist

PLATE 1. BEDROCK GEOLOGY OF THE GLENS FALLS-WHITEHALL REGION, NEW YORK

Donald W. Fisher
1985

Geological Survey,
New York State Museum, Map and Chart No. 35

Field Mapping (Paleozoic terrane) by Donald W. Fisher, 1957-60, 68-69, 73-77, 80-81.

Cartography by John B. Skiba and Ellen E. Crane, 1984-85

LEGEND

PHYSICAL AND ORGANIC CHARACTERISTICS

ECONOMIC AND ENVIRONMENTAL CHARACTERISTICS

AUTOCHTHONOUS STRATA

QUATERNARY (HOLOCENE & PLEISTOCENE)

AGE UNCERTAIN

LOWER PALEOZOIC

MIDDLE ORDOVICIAN (MOHAWKIAN SERIES)

TRENTON GROUP [Conrad, 1838]

BLACK RIVER GROUP [Vanuxem, 1842]

LOWER ORDOVICIAN (CANADIAN SERIES)

BEEKMANTOWN GROUP [Clarke & Schuchert, 1899]

LOWER ORDOVICIAN & UPPER CAMBRIAN (CANADIAN & CROIXAN SERIES)

UPPER CAMBRIAN (CROIXAN SERIES)

UPPER PROTEROZOIC (HADRYNIAN)

NON-METAMORPHOSED IGNEOUS (PLUTONIC) ROCK

MIDDLE PROTEROZOIC (HELIKIAN)

METAMORPHOSED IGNEOUS (PLUTONIC) ROCKS

METAMORPHOSED SEDIMENTARY AND IGNEOUS (VOLCANIC) ROCKS

LAKE GEORGE GROUP

PISECO LAKE GROUP [Wiener, et al., 1983]

ALLOCHTHONOUS STRATA (TACONIC SEQUENCE)

ORDOVICIAN & CAMBRIAN

MIDDLE ORDOVICIAN (CHAMPLAINIAN SERIES ?)

NORMANSKILL GROUP

LOWER ORDOVICIAN (CANADIAN SERIES) ? AND MIDDLE ORDOVICIAN (WHITEROCKIAN SERIES)

LOWER TO UPPER CAMBRIAN (TACONIAN AND CROIXIAN SERIES) AND LOWER ORDOVICIAN (CANADIAN SERIES)

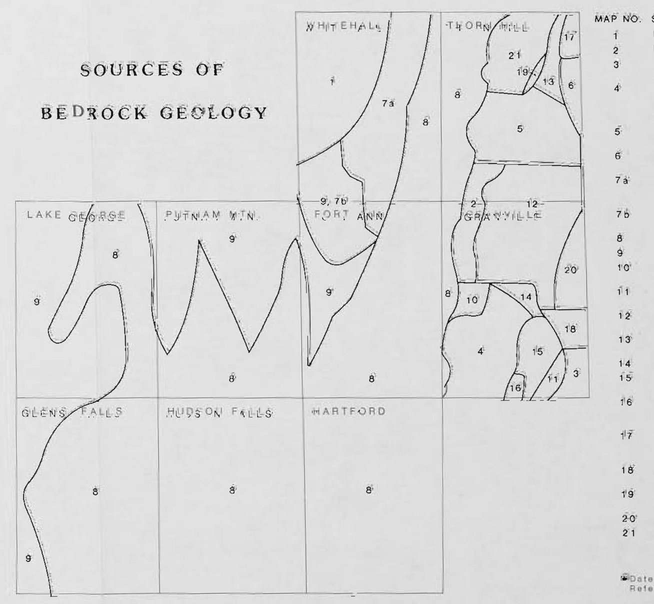
LOWER CAMBRIAN (TACONIAN SERIES)

CAMBRIAN (?)

SYMBOLS

NOTE

SOURCES OF BEDROCK GEOLOGY



NEW YORK STATE SCIENCE SERVICE
Richard H. Monheimer, Director

THE UNIVERSITY OF THE STATE OF NEW YORK
THE STATE EDUCATION DEPARTMENT

GEOLOGICAL SURVEY,
Robert H. Fakundiny, State Geologist

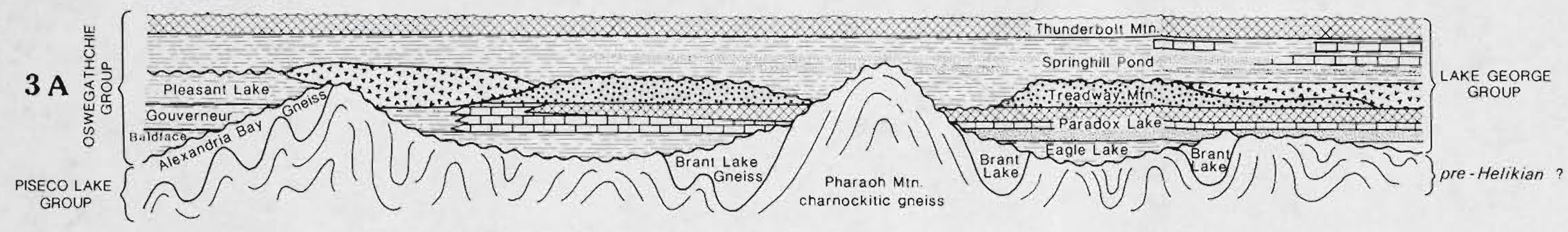
Fisher, Donald W. (1985)
Geological Survey,
N.Y.S. Museum, Map & Chart No. 35

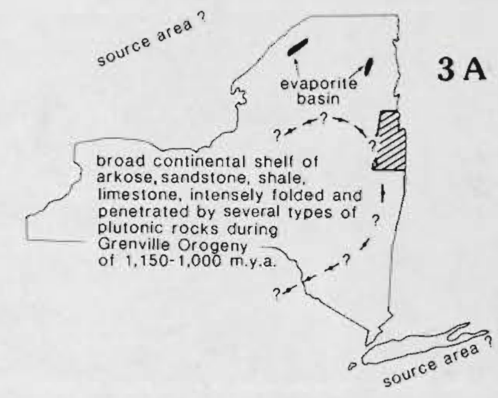
PLATE 2. STRUCTURE CROSS SECTIONS, GLENS FALLS-WHITEHALL REGION, NEW YORK

NEW YORK STATE GEOLOGICAL SURVEY
Geology by Donald W. Fisher with contributions by Robert H. Fakundiny and William Kidd
Graphics by John B. Skiba, 1985

MEDIAL PROTEROZOIC (HELIKIAN)
PRE 1,150 m.y.a.

3A

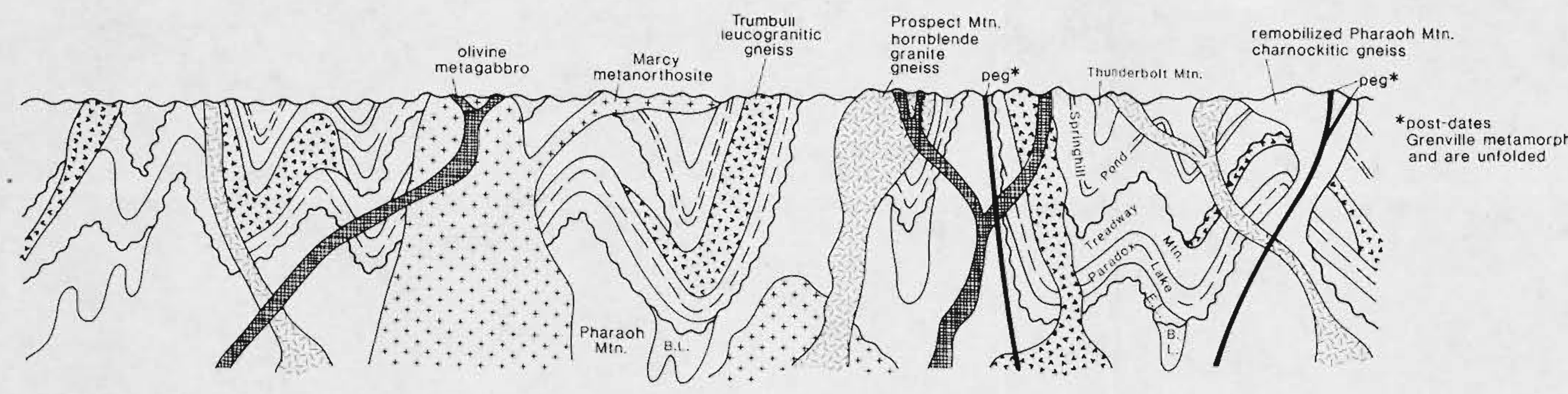




3A

1,150–950 m.y.a.
Folding and metamorphism of Lake George strata and subsequent igneous intrusions during Grenville Orogeny

3B



LAND
- Block fault; hachures on relatively downdropped side
- Inferred division between areas of low and high relief
- Average location of shore line

SEA
- Shelf
- Slope, Rise, Basin
- Division between inferred sea areas

SEDIMENTARY ROCKS
- Limestone
- Dolostone
- Shale; sometimes w/quartzite, limestone, conglomerate
- Quartzite, sandstone, siltstone
- Graywacke, arkose
- Conglomerate

METAMORPHIC ROCKS
- Olivine metagabbro
- Hornblende granitic gneiss
- Leucogranitic gneiss
- Metanorthosite
- Amphibolite

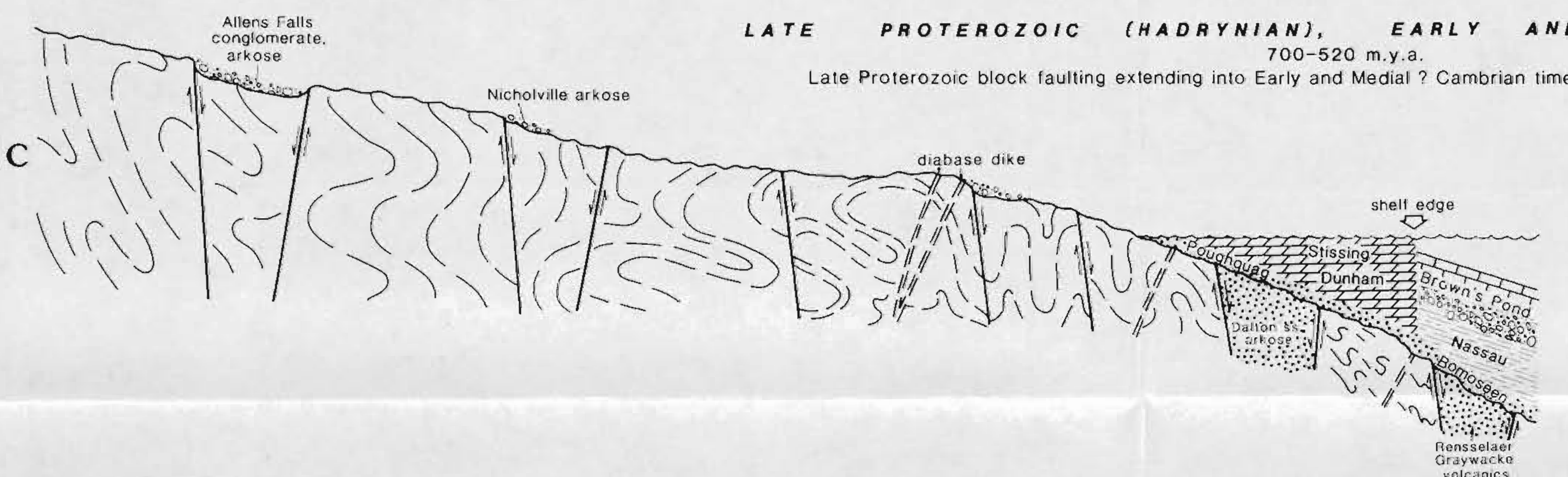
mapped area

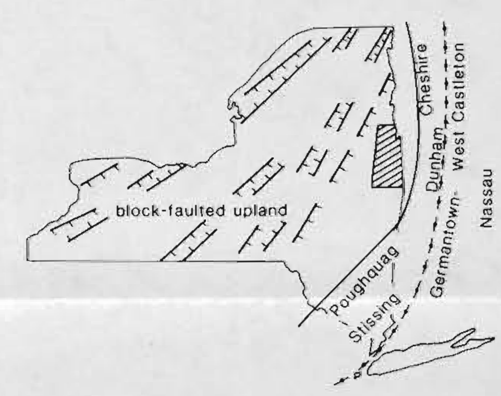
m.y.a. millions of years ago

Expanding Iapetus Ocean

LATE PROTEROZOIC (HADRYNIAN), EARLY AND MEDIAL CAMBRIAN
700–520 m.y.a.
Late Proterozoic block faulting extending into Early and Medial ? Cambrian times accompanied by diabase dikes

3C

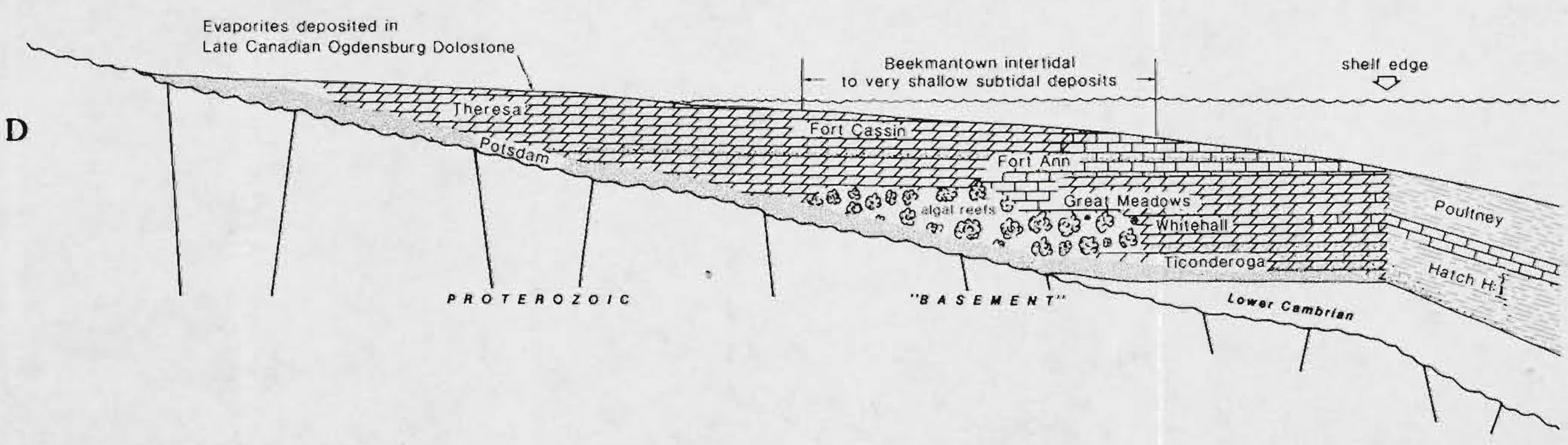


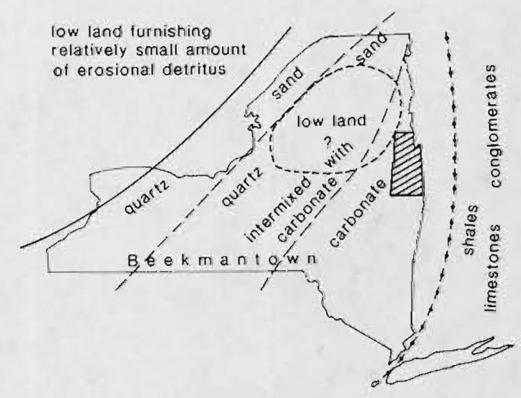


3C

LATE CAMBRIAN (CROIXIAN) AND EARLY ORDOVICIAN (CANADIAN)
520–470 m.y.a.

3D

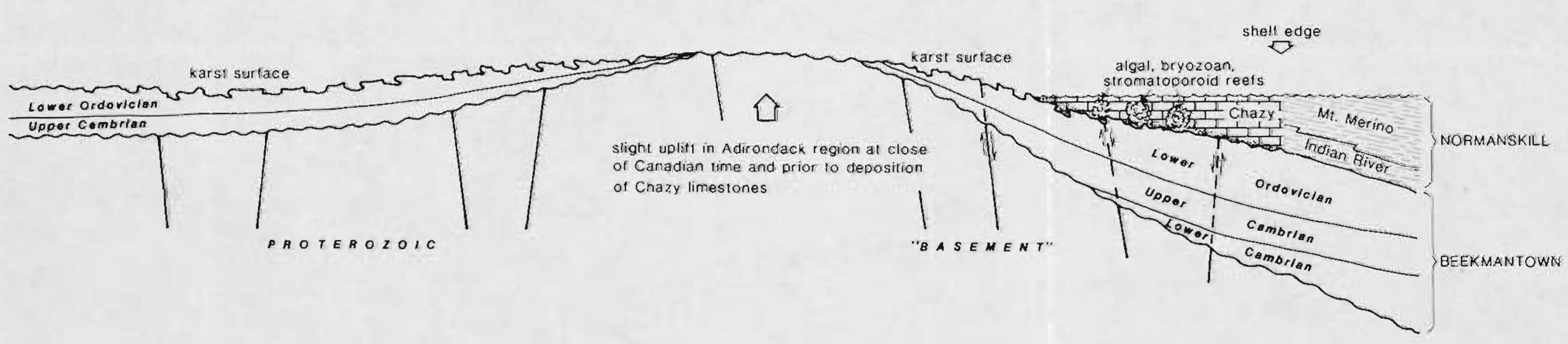


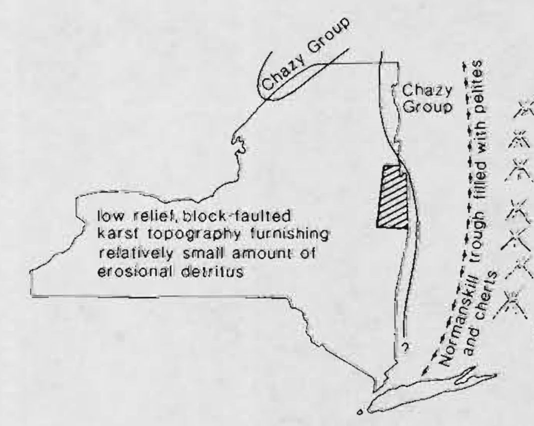


3D

EARLY - MEDIAL ORDOVICIAN (MONTYAN)
465–455 m.y.a.
Renewed block faulting at end of Early Ordovician time

3E

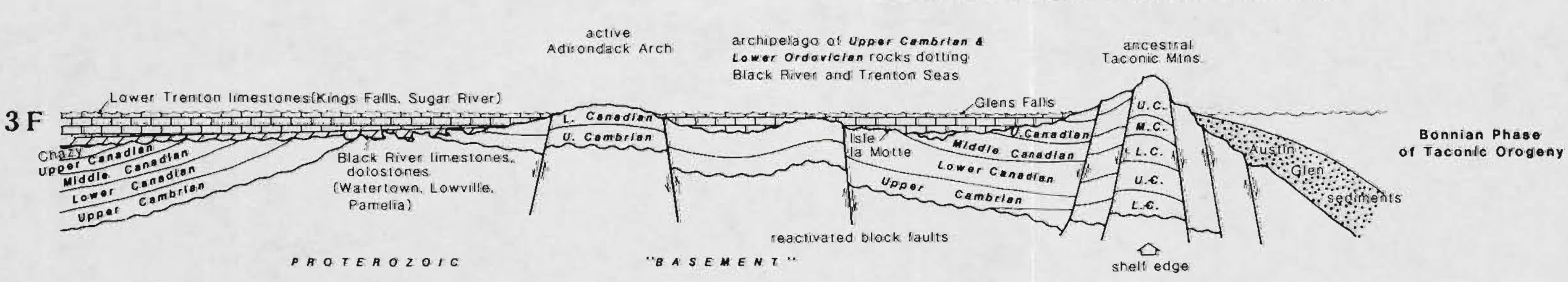


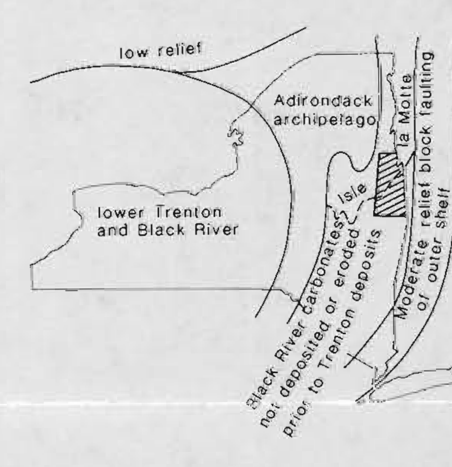


3E

LATE - MEDIAL ORDOVICIAN (TURINIAN)
450–445 m.y.a.
Following block faulting, the "Normanskill" Basin is elevated and reverse faulted westward

3F



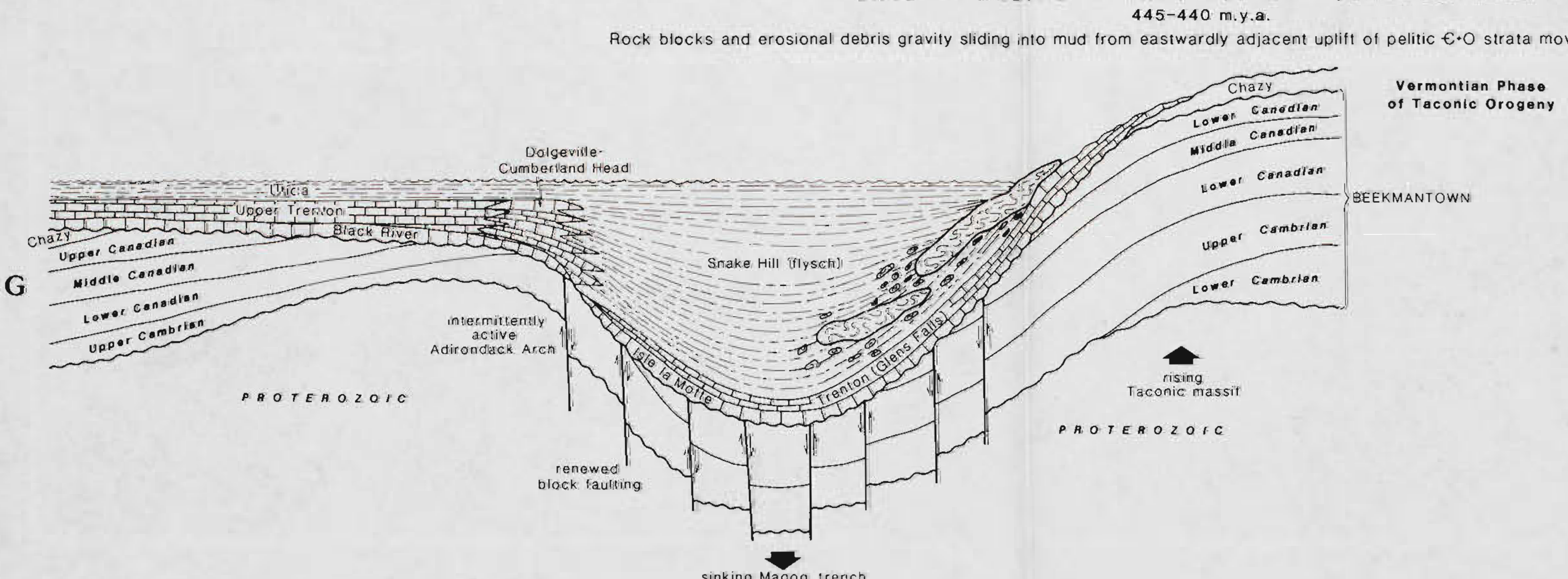


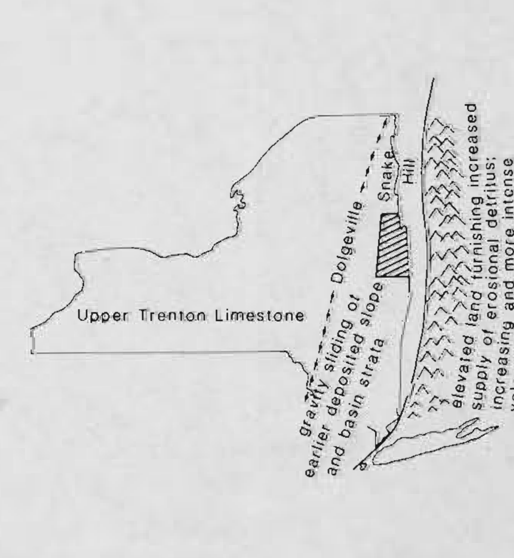
3F

Contracting Iapetus Ocean

LATE - MEDIAL ORDOVICIAN (CANAJOHARIE)
445–440 m.y.a.
Rock blocks and erosional debris gravity sliding into mud from eastwardly adjacent uplift of pelitic Є-O strata moving over shelf carbonates

3G

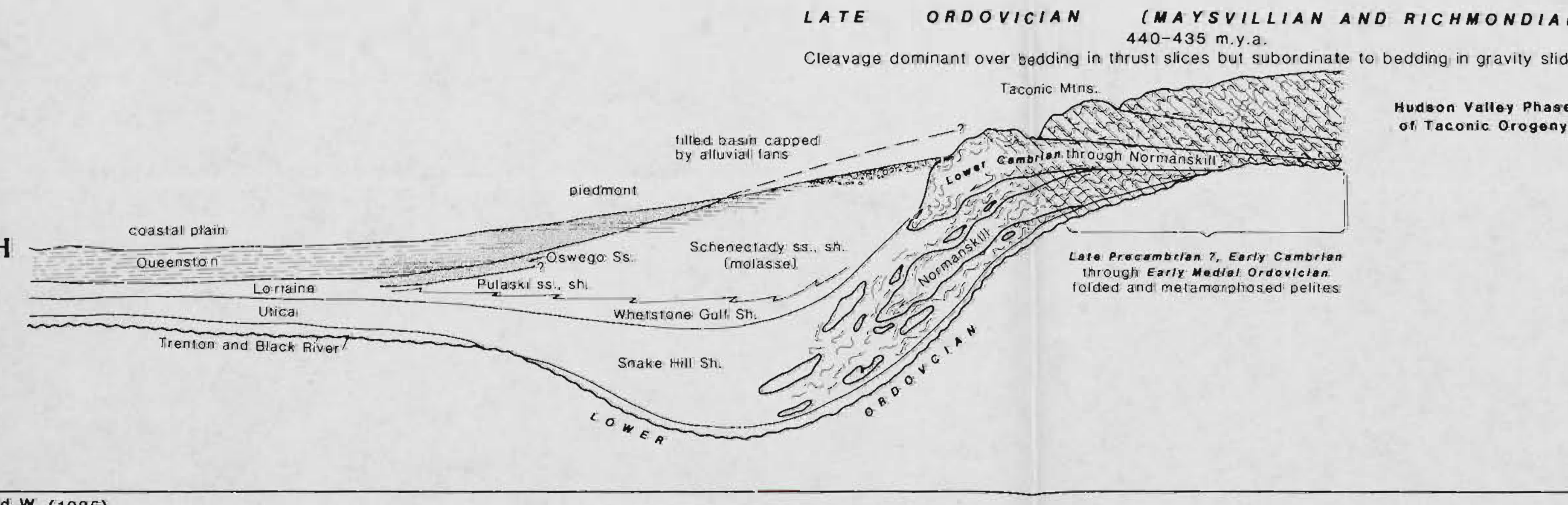


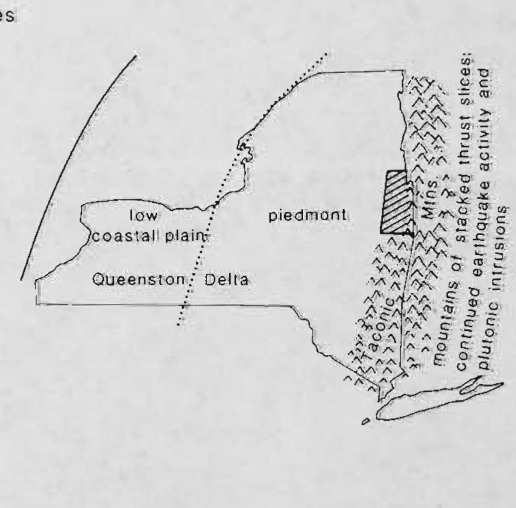


3G

LATE ORDOVICIAN (MAYSVILLIAN AND RICHMONDIAN)
440–435 m.y.a.
Cleavage dominant over bedding in thrust slices but subordinate to bedding in gravity slides

3H





3H

Fisher, Donald W. (1985)
Geological Survey,
N.Y.S. Museum, Map & Chart No.35

NEW YORK STATE GEOLOGICAL SURVEY
Interpretation: Donald W. Fisher
Graphics: John B. Skiba 10/81

PLATE 3. SCHEMATIC STRATIGRAPHIC PROFILES & PALEOGEOGRAPHIC MAPS, GLENS FALLS-WHITEHALL REGION, NEW YORK