

**GEOLOGY OF THE  
PALEOZOIC ROCKS  
OF THE  
GREEN POND OUTLIER**

*Maps  
Separate*

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GEOLOGY OF THE PALEOZOIC ROCKS  
OF THE GREEN POND OUTLIER

by

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## GEOLOGY OF THE PALEOZOIC ROCKS OF THE GREEN POND OUTLIER

### INTRODUCTION

Within the Precambrian Highlands of northern New Jersey and adjacent New York are several infolded and downfaulted belts of Paleozoic sediments. The easternmost of these belts, the Green Pond outlier, itself a downfaulted synclinal block, preserves Cambrian, Ordovician, Silurian, and Devonian rocks. The outlier extends for almost 55 miles northeastward from Flanders to Cornwall, New York, and attains a maximum width of 5 miles. The Paleozoic sediments of the outlier lie about 25 miles southeast of the main outcrop belt of the Appalachian Valley and Ridge Province of westernmost New Jersey. They represent sediments deposited approximately that much nearer the source areas to the east and provide a record of tectonic events and geographic conditions in the source area which are not detectable further west.

The outlier is particularly instructive because it illustrates in a small area the effects of the Taconic, Acadian and Appalachian Orogenies and the Newark Disturbance. In addition, it displays Appalachian folds and faults with unusually good exposures, especially those of the Shawangunk Formation and the Skunneunk Conglomerate.

The topography of the outlier is controlled by geologic structure and rock type. The dominant physiographic features are the northeasterly trending ridges of sandstones and conglomerates of the Shawangunk Formation and Skunneunk Conglomerate where they are exposed in flanks and cores of folds. The intermediate elevations are occupied by the less resistant Bellvale Sandstones and the valleys contain the remaining formations, which are even less resistant.

## CAMBRIAN SYSTEM

### Hardyston Sandstone

The Hardyston Sandstone of Early Cambrian Age is the oldest sedimentary formation in the outlier and rests unconformably on Precambrian gneisses. Exposures are generally poor but it is partly exposed at and near the abandoned Gould's Quarry, 600 feet southwest of a sharp turn on Gould Road, 1.0 mile from its junction with Echo Lake Road, Echo Lake.

The Hardyston is composed of nonfossiliferous blue-gray conglomeratic sandstone, grading upward into calcareous sandstone, which in turn grades upward into the Kittatinny Dolomite. The Hardyston is approximately 100 feet thick at Gould's Quarry.

### Kittatinny Dolomite

The Kittatinny Dolomite of Early Cambrian Age only occurs north of Newfoundland and south of Picatinny Lake. It is generally poorly exposed, but good outcrops are present at Gould's Quarry. This formation was called the Leithsville Formation on Geologic Overlay Sheet 22 of the New Jersey Geologic Survey.

The Kittatinny is composed of slightly fossiliferous medium-gray massive dolomite which weathers yellow-buff.

The Kittatinny is unconformably overlain by the Early to Middle Silurian Shawangunk Formation. In most of the outlier, pre-Shawangunk erosion removed the entire Kittatinny (which was originally about 2,500 feet thick). At Gould's Quarry only about 35 feet remain. The erosional contact is well displayed at this locality. The erosional surface is quite irregular and displays evidence of having been an ancient karst surface. Solution cavities filled with Shawangunk conglomerate occur as much as 30 feet below the erosional surface.

## ORDOVICIAN SYSTEM

### Martinsburg Shale

The only exposures of the Martinsburg Shale are small ones on the north end of the east bank of the west arm of Oak Ridge Reservoir. This area was extensively faulted and exposures are poor.

The Martinsburg is composed of dark gray shale with prominent slaty cleavage and orange-buff weathered siltstone. The siltstone, which is only exposed when the reservoir is very low, contains abundant Late Ordovician brachiopods. No determination of formation thickness could be made due to the structural complications.

## SILURIAN SYSTEM

### Shawangunk Formation

The Shawangunk Formation of Early to Middle Silurian Age was referred to as the Green Pond Formation by Kummel and Weller (1902) and on Geologic Overlay Sheet 22 of the New Jersey Geologic Survey. It is a very well exposed resistant formation which makes up almost the entire mass of Copperas, Kanouse, Green Pond, and Bowling Green mountains. A particularly good exposure is at a roadcut along Route 23, 1.0 mile east of Newfoundland.

The Shawangunk is composed of nonfossiliferous purple-red conglomerate interbedded with and grading upward into purple-red sandstone. These rocks have been strongly cemented by quartz cement. The conglomerate pebbles range from one-half to three inches in diameter and are almost entirely white quartz, but minor black, white, yellow and red chert, red shale and red sandstone also occur. The pebbles of the lowest conglomerate beds are quite angular but those higher in the formation are more rounded. The Shawangunk grades upward into the High Falls Shale.

The lower contact of the Shawangunk is unconformable. Between Newfoundland and Dover this unit rests on Precambrian gneisses indicating that a large uplift had taken place and about 12,000 feet of Cambrian and Ordovician strata had been eroded. Between Newfoundland and the New York State border the Shawangunk rests on the Kittatinny Dolomite but only about 35 feet of Kittatinny remains. Therefore, pre-Shawangunk erosion was almost 12,000 feet in that area as well. On the west side of Oak Ridge Reservoir the Shawangunk rests on the Martinsburg Shale. In this local area far less erosion of the underlying strata took place. This could well be just a localized situation since 3 miles to the south at Bowling Green Mountain the Shawangunk rests on Precambrian gneisses.

The Shawangunk is about 1000 feet thick in the Newfoundland area.

### High Falls Shale

The High Falls Shale was called the Longwood Shales by Kummel and Weller (1902) and is approximately correlative with the Bloomsburg Formation of westernmost New Jersey. The High Falls is quite poorly exposed. The best exposures are located on the west side of Green Pond Mountain between Oak Ridge Lake and Longwood Lake.

The High Falls is composed of nonfossiliferous purple-red silty shales with some slaty cleavage. Thin red sandstone beds are present in the lower part. This unit is about 300-350 feet thick at Longwood Lake.

### Poxono Island Formation

The best exposure of the Poxono Island is at Woodstock, 500 feet south of Oak Ridge Lake. The Poxono Island beds at Woodstock were referred to as the Decker Ferry Formation by Kummel and Weller (1920).

Although the Poxono Island displays a varied lithologic nature, it is dominated by sublithographic nonfossiliferous dolomite. It is in three distinct colors, medium gray, greenish gray, or yellow and weathers grayish yellow. Beds range from 1 in. to 2 feet in thickness and commonly are faintly laminated. Mudcracks, whose interstices are filled with green shale, dessication fragments, and sand are common.

Commonly interbedded with dolomites are medium-grained, cross-bedded sandstones, from 6 in. to 3 feet thick, which are greenish yellow in color when fresh and weather grayish yellow. Green and purple silty shale and green siltstone from 0.25 to 1 in. thick are often closely interbedded with the dolomite. The transition from green to purple shale is often marked by a zone of bluish-gray shale 0.5 in. thick or less.

The lower contact is exposed at Woodstock, where green shales of the Poxono Island Formation are in gradational contact over a 3 foot interval with the underlying purple silty shales of the High Falls Shale.

The Poxono Island Formation is approximately 350 feet thick at Longwood Lake.

#### Berkshire Valley Formation

The Poxono Island Formation is conformably overlain by the Berkshire Valley Formation which in turn is overlain disconformably by the Connelly Conglomerate. The type section is located 1700 feet southeast of the dam of Upper Longwood Lake. A reference section is 400 feet southwest of the type section. This unit was called the Decker Formation by Kummel and Weller (1902) and Weller (1903) and is included within the Poxono Island on Geologic Overlay Sheet 22 of the New Jersey Geologic Survey.

The Berkshire Valley of Late Silurian Age is composed predominantly of fossiliferous, calcareous siltstone with abundant lenses and beds of fossiliferous, sublithographic, silty dolomite. The siltstone is gray or greenish gray when fresh, and the dolomite is medium gray. Both rocks weather yellow gray. Beds range in thickness from 1 to 10 in. Numerous partings of olive-gray shale occur in the basal beds. Bryozoans, brachiopod fragments, and some pelmatozoan ossicles usually occurring in lenses, constitute from 10 to 20 percent of both the siltstone and dolomite. At the type section, 12 feet of sandstone and conglomerate occur 39 feet above the base of the formation. Most of the conglomerate contains quartz pebbles, but there is also a 2 foot bed of subround, sublithographic, carbonaceous, limestone pebbles in a matrix of very fine-grained, green sandstone.

The Berkshire Valley is known only in the southern part of the outlier. The only complete section of the Berkshire Valley is 126 feet thick at the type section. In addition to the bedrock occurrences, large glacial erratics of the Berkshire Valley Formation are scattered about a large area from 1 to 2 miles northeast of Green Pond, New Jersey. The occurrence of fossils in these boulders has been known since Cook (1868) noted their presence on the Cobb property 1.5 miles south of the railroad depot at Newfoundland, New Jersey. Kummel and Weller (1902) presented faunal lists for this locality.

The ~~Berkshire Valley Formation at Longwood Lake~~ correlates with the entire Clove Brook Member of the Decker Formation of westernmost New Jersey.

## DEVONIAN SYSTEM

### Connelly Conglomerate

The Connelly Conglomerate of Early Devonian Age unconformably overlies the Berkshire Valley Formation and is considered to be the equivalent of the Oriskany Sandstone. It was included within the Kanouse Sandstone on Geologic Overlay Sheet 22 of the New Jersey Geologic Survey. The only exposure is at the south end of Greenwood Lake about 100 feet west of Reidy Place.

The Connelly is composed predominantly of quartz pebble conglomerate with abundant quartz sand between the pebbles. The rock is white when fresh and weathers tan and pink. Some silicified brachiopods are present.

Only about five feet of Connelly are exposed at Greenwood Lake, but the total thickness where it is exposed at Monroe, New York, is 38 feet. Along Route 23 in Newfoundland the Connelly, Esopus and Kanouse were exposed briefly in 1964 and 39 feet of Connelly was measured.

### Esopus Formation

The Esopus Formation of Early Devonian Age unconformably overlies the Connelly Conglomerate. It was included within the Kanouse Sandstone on Geologic Overlay Sheet 22 of the New Jersey Geologic Survey. Best exposures are at the south end of Greenwood Lake starting at the Connelly outcrop and continuing west up to the top of the hill.

The Esopus Formation contains five members. In ascending order they are Mountainville, Lower Black Mudstone, Highland Mills, Upper Black Mudstone, and Woodbury Creek. The stratigraphic relationships of these members are shown in Figure 1. The lower four members are correlative with the Esopus of westernmost New Jersey and the Woodbury Creek correlates with the Schoharie Formation (Boucot, et al., 1970).

The Mountainville Member consists of light to dark-gray siltstone. Many bedding planes show Taonurus markings (fan shaped animal trails). No other fossils are present. This unit is 25 feet thick at Greenwood Lake.

The Lower Black Mudstone Member consists of dark-gray to black nonfossiliferous mudstone. It is 110 feet thick at Greenwood Lake.

The Highland Mills Member is composed of light-gray or bluish-gray fine sandstone and siltstone. It is nonfossiliferous at Greenwood Lake but contains an abundant amount of fauna at Highland Mills, New York (Boucot, et al., 1970). This member is 90 feet thick at Greenwood Lake.

The Upper Black Mudstone Member is composed of black mudstone and siltstone. Taonurus markings are abundant, but no other fossils are present. The unit is 55 feet thick at Greenwood Lake.

The Woodbury Creek Member is composed of light-gray to medium-gray siltstone and fine sandstone. Although fossils are present at Highland Mills, New York, this unit is nonfossiliferous at Greenwood Lake. Thickness is about 70 feet.

#### Kanouse Sandstone

The Kanouse Sandstone of Early Devonian Age is correlative with the Schoharie Formation of westernmost New Jersey, and was referred to as the Newfoundland Grit by Kummel and Weller (1902). The best exposures are at the south end of Greenwood Lake along the ridge at the western end of the Esopus Formation outcrops. This ridge continues northward ending at a point in the lake 0.5 mile south of the New York State border.

The lower part of the Kanouse is a sequence of interbedded conglomerate and sandstone. Both are tightly cemented by quartz. They are gray when fresh and weather brown. The conglomerate pebbles are very small and well rounded. The upper part of the Kanouse is mostly sandstone which is more readily weathered than the lower part of the formation. The Kanouse is somewhat fossiliferous at Greenwood Lake.

Since the upper contact of the Kanouse is not exposed the exact thickness is unknown. About 50 feet are exposed at Greenwood Lake and the total thickness is probably not much greater.

#### Marcellus Shale

The Marcellus Shale of Middle Devonian Age was called the Monroe Shales by Kummel and Weller (1902). Parts of this formation are exposed in many places but the most complete exposure is immediately west of the Kanouse Sandstone point on Greenwood Lake, 0.5 mile south of the New York State border. The Kanouse is exposed to the east of Route 511 and the Marcellus to the west.

The Marcellus is composed of very dark gray slightly silty shale and is only slightly fossiliferous. Silt becomes more abundant in the upper part of the formation. Slaty cleavage is quite prominent in most areas. The Marcellus is about 600 feet thick at Greenwood Lake.

#### Bellvale Sandstone

The Bellvale Sandstone of Middle Devonian Age is exposed in many places in the outlier, but the best exposure is at Greenwood Lake on the hill west of Route 511, 0.5 mile south of the New York State border.

The Bellvale consists of interbedded black shale, black siltstone and flaggy bedded medium gray sandstone. Shale and siltstone are more abundant



in the lower part. The uppermost beds grade into the overlying Skunnemunk conglomerate. These transition beds contain red and green sandstone and shales. Only a few fossils have been found and they came from the outlet of the Oak Ridge Reservoir (Kummel and Weller, 1902). The Bellvale is about 2000 feet thick at Greenwood Lake.

#### Skunnemunk Conglomerate

The Skunnemunk Conglomerate of Middle Devonian Age is the youngest formation in the outlier. It is a very well exposed, resistant formation, which makes up most of Bearfort Mountain from the Clinton Reservoir northward to the New York State border.

The Skunnemunk is composed of interbedded reddish-purple conglomerate, red sandstone and red shale. The sandstone and conglomerate are very strongly cemented by quartz cement. The conglomerate pebbles are quite large and well rounded, some are six inches in diameter. About half of them are white milky vein quartz and the other half are mostly purple sandstone, purple shale and minor purple conglomerate, chert and siliceous limestone. No fossils have been found in this unit. Since the top of the Skunnemunk has been eroded, the total thickness is unknown. About 3000 feet are exposed on Bearfort Mountain.

### STRUCTURAL GEOLOGY

The outlier is a large syncline which has been downfaulted on its western side. The northern extension of the outlier in New York is downfaulted on both sides. At the New York State border only the syncline is present, but to the south three anticlines and synclines developed on its eastern flank. Throughout at least part of their length each anticline-syncline pair has been faulted by a high angle fault parallel to the axes of the folds. In each case the eastern block was downdropped relative to the western block. South of Bowling Green Mountain the only Paleozoic exposures are the easternmost fold pair. The only area where overturned beds are present is in the northern portion of the outlier, on the east limb of the major syncline.

### STRUCTURAL HISTORY

#### Cambrian Period

Prior to the deposition of the Hardyston Sandstone, the Precambrian gneisses were uplifted and eroded. In the Early Cambrian the Hardyston was deposited on the resulting erosion surface. Hardyston deposition then gave way to the shallow water carbonates of the Kittatinny Dolomite which were probably deposited during a time interval spanning the Early Cambrian to the Early Ordovician.

## Ordovician Period

Kittatinny deposition probably ended in the Early Ordovician with regional uplift and erosion following. It is not known whether the Middle Ordovician limestones of westernmost New Jersey were deposited in the outlier. In the Late Ordovician the Martinsburg Shale, deposited in a deep basin, was followed by uplift and erosion related to the Taconic Orogeny. The only area within the outlier where significant Taconic deformation seems to have taken place is at and near Oak Ridge Reservoir. There the Martinsburg is present beneath the pre-Shawangunk erosional surface, whereas at Bowling Green Mountain immediately to the south and Green Pond Mountain to the east, erosion removed the entire Cambro-Ordovician sequence (at least 3000 more feet of erosion). Therefore, substantial folding and/or faulting must have occurred in that area.

Taconic uplift was greatest in the Newfoundland area and decreased markedly in all directions. This led Finks (1968) to postulate that the Newfoundland area was an island. However, it more probably was the highest part of a quite widespread Taconic uplifted area.

## Silurian Period

Erosion continued until the Middle Silurian when the fluvial Shawangunk Formation and succeeding High Falls Shale were deposited. A marine transgression developed in the Late Silurian when the Poxono Island and Berkshire Valley Formations were deposited. The outlier was then uplifted in either the latest Silurian or Early Devonian. This uplift was restricted to the outlier and in fact did not even develop in the northern extension of the outlier at nearby Cornwall, New York.

## Devonian Period

In the Early Devonian the Connelly Conglomerate was deposited in shallow marine conditions. After a short erosional break the Esopus Formation and Kanouse Sandstone of shallow to medium depth marine origin were deposited. In the Middle Devonian, deposition of the deep water marine Marcellus Shale was followed by a prograding sequence of massive delta which was being formed as the result of the Acadian Orogeny uplift to the east. The prodelta, foreset beds, and topset beds are represented by the Bellvale Sandstone and the fluvial deposits by the Skunnemunk Conglomerate.

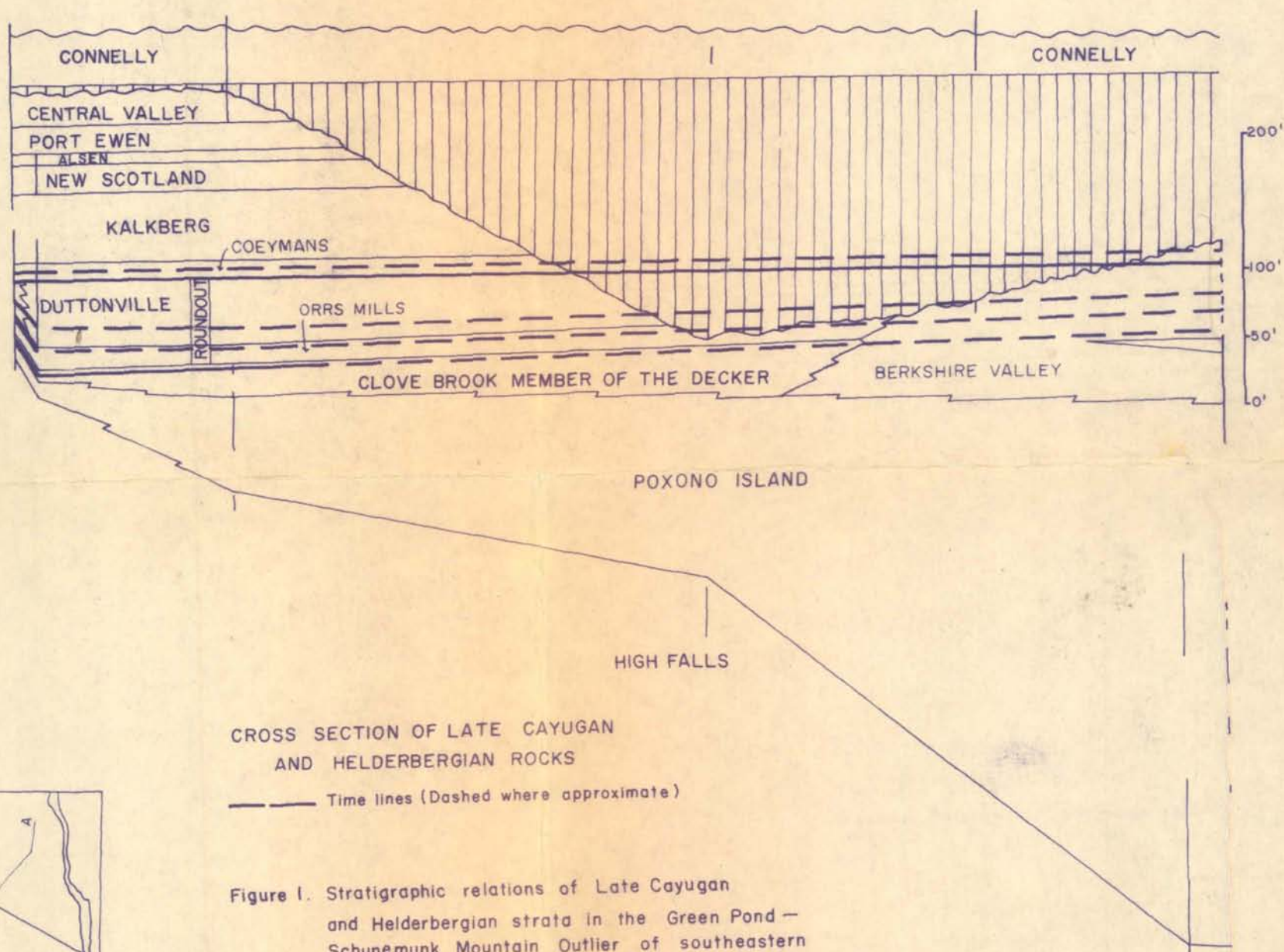
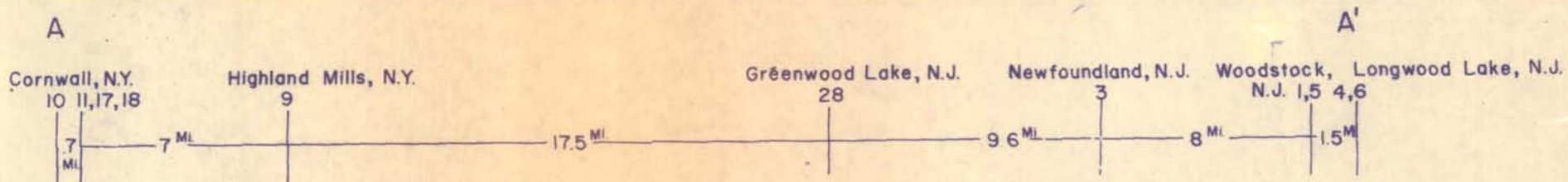
## Post-Devonian

The folding of the Paleozoic sediments took place after the Middle Devonian. It could have taken place in the latter part of the Acadian Orogeny, but more likely it was in the late Paleozoic Appalachian Revolution. The high angle normal faulting probably developed in the Triassic as part of the Newark Disturbance.

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SYSTEM	SERIES
DEVONIAN	HELDERBERGIAN
SILURIAN	CAYUGAN



CROSS SECTION OF LATE CAYUGAN AND HELDERBERGIAN ROCKS  
 --- Time lines (Dashed where approximate)

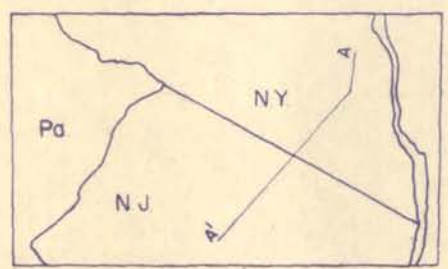
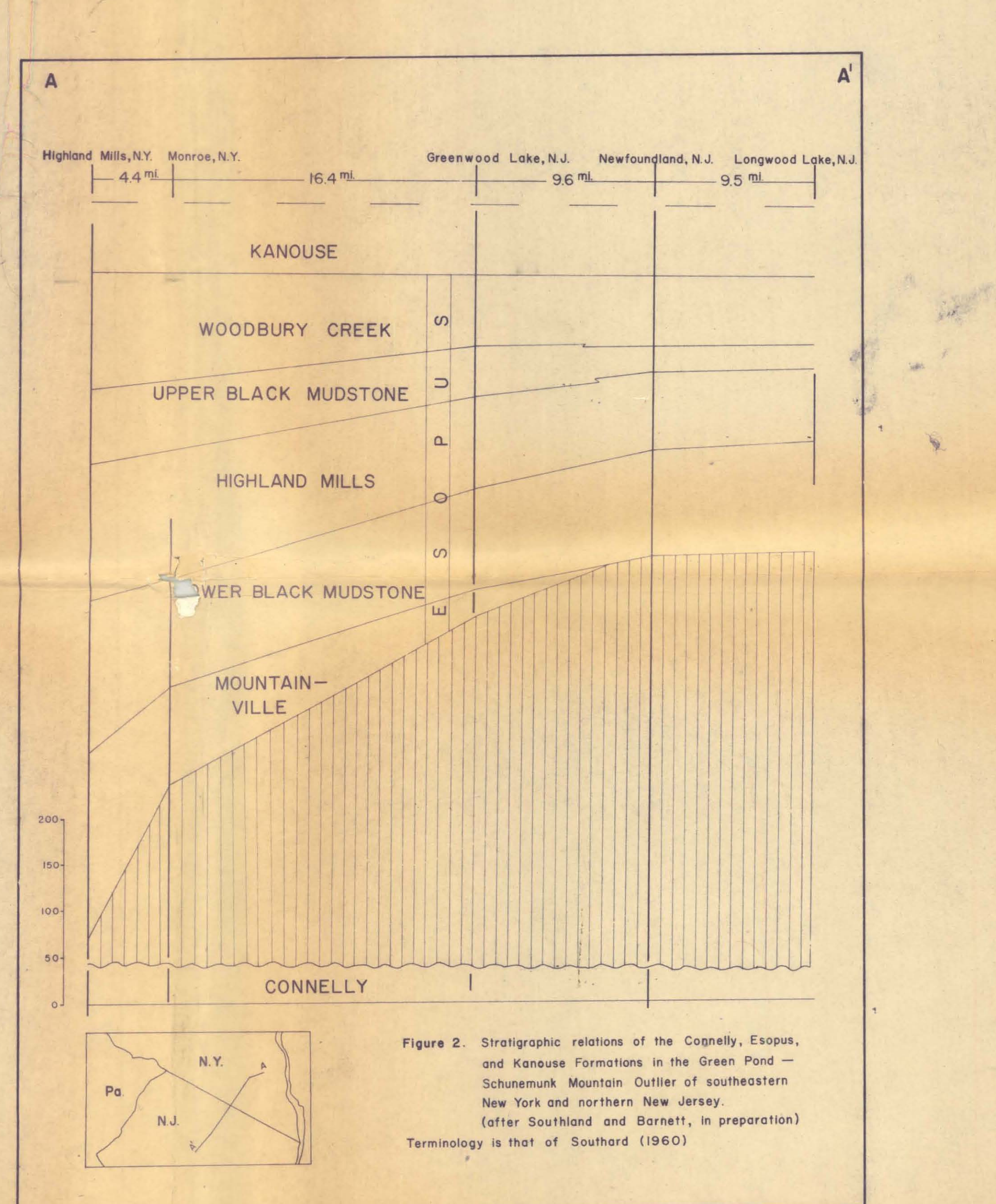
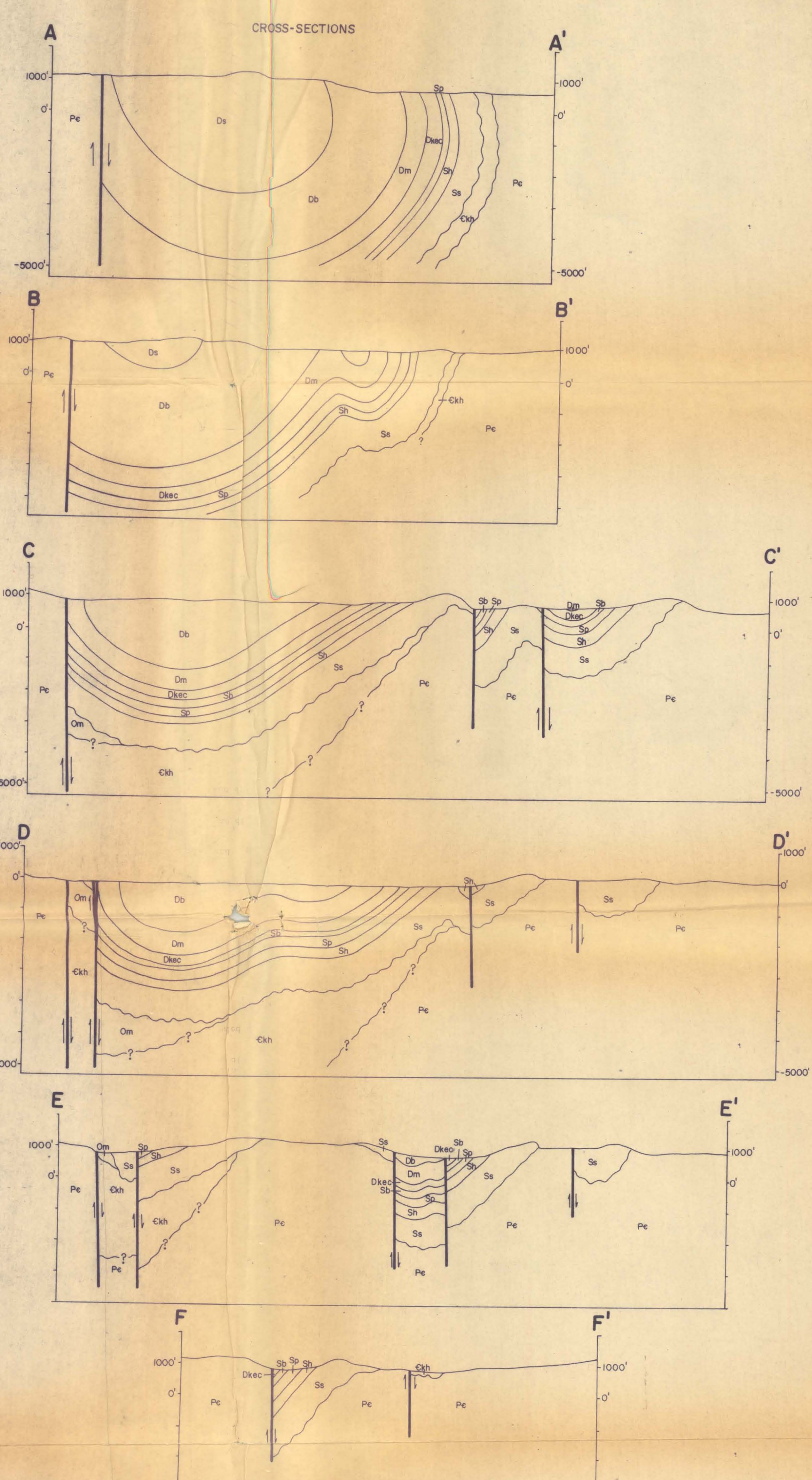


Figure 1. Stratigraphic relations of Late Cayugan and Helderbergian strata in the Green Pond - Schunemunk Mountain Outlier of southeastern New York and northern New Jersey. (after Barnett, 1970)

GEOLOGIC MAP OF THE GREEN POND OUTLIER  
NEW JERSEY

LEGEND

- |              |        |                |  |
|--------------|--------|----------------|--|
| DEVONIAN     | MIDDLE | <b>Ds</b>      | CONGLOMERATE   |
|              |        | <b>Db</b>      | WAZZILLA SANDSTONE   |
|              |        | <b>Dm</b>      | MARCELLUS SHALE  |
|              |        | <b>Dac</b>     | KANOUSE SANDSTONE, EGEPUS FORMATION, and CONNELLY OVERBURDEN   |
| DEVONIAN     | LOWER  | <b>Pe</b>      | Light gray coarse sandstone and conglomerate (Kanoose) overlies buff sandstone, gray siltstone, and black shale with slaty cleavage (Egopus) which overlies unconformably white to buff coarse sandstone and conglomerate (Connellly). |
|              |        | (UNCONFORMITY) |  |
|              |        | <b>Ss</b>      | BERKSHIRE VALLEY FORMATION   |
|              |        | <b>Sp</b>      | WOODS ISLAND FORMATION   |
| SILURIAN     | UPPER  | <b>Sh</b>      | Green, gray, and buff dolomite with some red silty shale and thin sandstone beds (includes Berkshire Valley Formation in the northern area)  |
|              |        | <b>Sn</b>      | HIGH FALLS SHALE   |
|              |        | <b>Sa</b>      | SUSANCONK FORMATION  |
|              |        | (UNCONFORMITY) |  |
| ORDOVICIAN   | UPPER  | <b>Om</b>      | MARTINSBURG SHALE  |
|              |        | (UNCONFORMITY) |  |
| CAMBRIAN     | LOWER  | <b>Ckh</b>     | KITTATINNY MARLITE and BABOYSTON SANDSTONE   |
|              |        | (UNCONFORMITY) |  |
| PRE-CAMBRIAN | LOWER  | <b>Pc</b>      | TRONDHJEMIAN (gneiss and granite)  |
|              |        | (UNCONFORMITY) |  |
- Formation Contacts
- - - - - Dashed where approximately located
  - ..... Concealed
- Faults
- - - - - Dashed where approximately located
  - ..... Concealed
  - .....?..... Doubtful or probable, dotted where concealed
  - U High angle fault
- Folds
- 20 Anticline (showing trace of axial plane and bearing and plunge of axis. Dashed where approximately located)
  - ..... Concealed anticline
  - 11 Syncline (showing trace of axial plane and bearing and plunge of axis. Dashed where approximately located)
  - ..... Concealed syncline
  - Horizontal fold axis
- 30 Strike and dip of beds
- 50 Strike and dip of vertical beds
- 40 Strike and dip of overturned beds
- 40 Strike and dip of slaty cleavage



CONTOUR INTERVAL 20 FEET  
(SCALE IN FEET AND METERS)

ROAD CLASSIFICATION

- Heavy duty
- Medium duty
- Light duty
- Unimproved dirt
- State Route

THIS MAP COMPLETES WITH NATIONAL MAP ACCURACY STANDARDS FOR SALE BY U. S. GEOLOGICAL SURVEY, WASHINGTON 25, D. C. A FOLDER INCLUDING TOPOGRAPHIC MAPS AND EVIDENCE IS AVAILABLE ON REQUEST

