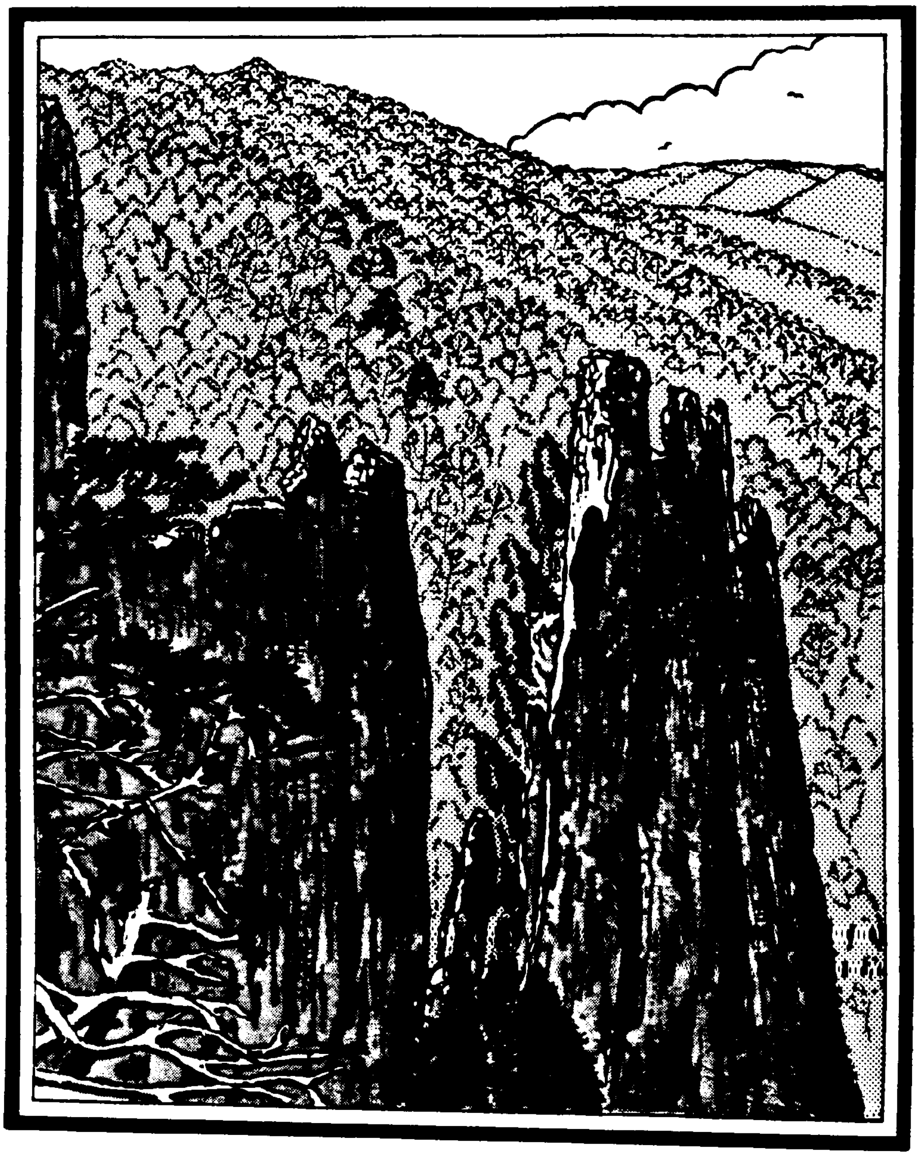
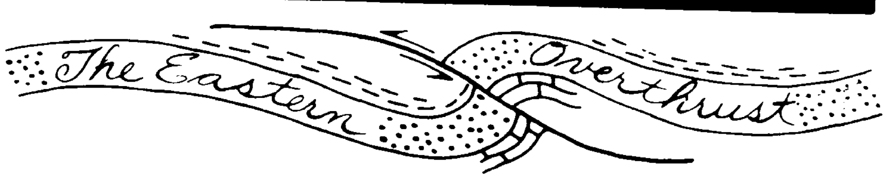
APPALACHIAN GEOLOGICAL SOCIETY

Golden 50th Anniversary

FIELD TRIP GUIDE BOOK





APPALACHIAN GEOLOGICAL SOCIETY
FIELD TRIP GUIDEBOOK

THE STRUCTURAL DEVELOPMENT AND DEFORMATION OF THE ALLEGHENY FRONTAL ZONE AND WILLS MOUNTAIN ANTICLINORIUM - THE CENTRAL EASTERN OVERTHRUST BELT -

FIELD TRIP ORGANIZERS AND LEADERS

RICHARD A. DRABISH - COLUMBIA GAS TRANS. CORP.

ROY S. SITES - MORRIS EXPLORATION CO.

APRIL 20, 1982

CUMBERLAND, MARYLAND TO PETERSBURG, WEST VIRGINIA

APRIL 21, 1982

PETERSBURG, WEST VIRGINIA TO FRANKLIN, WEST VIRGINIA

APRIL 22, 1982

FRANKLIN, WEST VIRGINIA TO CUMBERLAND, MARYLAND

= Forward =

"... and some rin up hill and down dale, knapping the chunky stances to pieces wi' hammers, like sae many road-makers run daft. They say 'tis to see how the world was made!"

Sir Walter Scott, "St. Roman's Well"

1824

PREFACE

The central portion of the "Eastern Overthrust Belt" in West Virginia's eastern counties is not a newly developed exploratory area. Explorationists have, for decades, been trying to unravel the geologic mysteries of the surface and subsurface strata of this area. Now with the added knowledge of subsurface information from recent exploratory drilling, and better seismic data, some of the eastern United States' most complex structural geology is becoming easier to understand.

The primary purpose of the "Eastern Overthrust" field trip is three-fold: First, to show the structural connotation and style of deformation for the Silurian through Lower Devonian package of rock within the Wills Mountain anticlinorium and the Allegheny Frontal zone; secondly, to show and explain some of the stratigraphy of the above rock package with special emphasis being placed on the reservoir characteristics of the Oriskany and Tuscarora Sandstone Formations; and finally, to show the predictability of and similarities between surface and subsurface structures by comparing one locale with another.

In a radically deformed area such as the "Eastern Overthrust Belt", it is of the utmost importance to understand, as precisely as possible, the exposed rock structures. Both surface and subsurface structural deformation, style and connotation are repetitious over very large areas. By predicting repetition of structures using analogies, geologists can hopefully increase their chances of predicting the occurrence of hydrocarbons.

Richard Drabish
Senior Geologist
Columbia Gas Transmission Corporation

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ACKNOWLEDGEMENTS

The organizers of this field trip wish to acknowledge the Appalachian Geological Society for the opportunity to present a detailed look at a portion of one of the most intriguing geologic provinces within the Appalachain Basin. We would also like to mention our appreciation for the financial assistance and employee time contributed by Columbia Gas Transmission Corporation and Morris Exploration Company. Without their help this project could not have been accomplished.

In preparing the field trip guidebook, special thanks goes to those people at Columbia Gas Transmission Corporation and Morris Exploration Company who helped draft various figures, typed the text and gave a critical review of its contents. Particularly, Mr. William H. Hawley, Jr. (Columbia Gas) who illustrated the various pictures within the text and the cover, and Mrs. Helen Chapman (Columbia Gas) who did an excellent job on writing the various quotes, etc. in script. Mr. John Daskalos (Columbia Gas), Mrs. Donna Brown (Columbia Gas) and Ms. Ann Berger (Morris Exploration) are to be credited with drafting some of the numerous figures and cross sections found in the text. Ms. Kristi Wheatley (Columbia Gas), Mr. Bob McFarland (Columbia Gas) and Ms. Brenda Browning (Morris Exploration) are to be credited with typing the text. Mr. Ed Rothman (Editor, Appalachian Geological Society) gave a critical review of its contents.

A special thanks is noted for Mr. Richard Beardsley, Chief Geophysicist, Columbia Gas Transmission Corporation for the preparation, thought, and willingness to write a very interesting innovative paper on the "Depositional and Deformational History of the Appalachian Basin."

Finally, we wish to thank Ms. Lee Avary of the West Virginia Geological and Economic Survey for her work on preparing the field trip road log (See Appendix).

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January, 1982

TO THE SOCIETY'S MEMBERSHIP AND FELLOW GEOLOGISTS:

The Appalachian Geological Society celebrated its 50th anniversary in 1981. Since its formation as the Charleston Geological Society in March 1931, the society has promoted the interests of the oil and gas industry in the Appalachian Basin and provided a forum for exchanging new ideas in the field of geology.

The Society's first publication was in 1937. Several additional guidebooks and symposiums have been published since that time in an attempt to keep geologists informed on new areas of interest. The Eastern Overthrust Belt has recently become a center of interest for many oil and gas operators, and it is certainly one of the most challenging frontier areas confronting geologists today. Because of this interest the A.G.S. decided in the spring of 1981 to sponsor a field trip through an area of recent drilling activity in the eastern panhandle of West Virginia. The Society's president at that time, Bill Bagnall, contacted Roy Sites; who together with Rich Drabish, planned, organized, and will lead the field trip. The Society is deeply indebted to Roy and Rich for the time and effort they have put into the project. I would also like to thank the other A.G.S. officers for their comments and suggestions, and especially our editor, Ed Rothman, who handled the proof-reading and publication of the guidebook.

It is the hope of all of the officers that this field trip and guidebook will mark the beginning of another 50 years of active service to the profession.

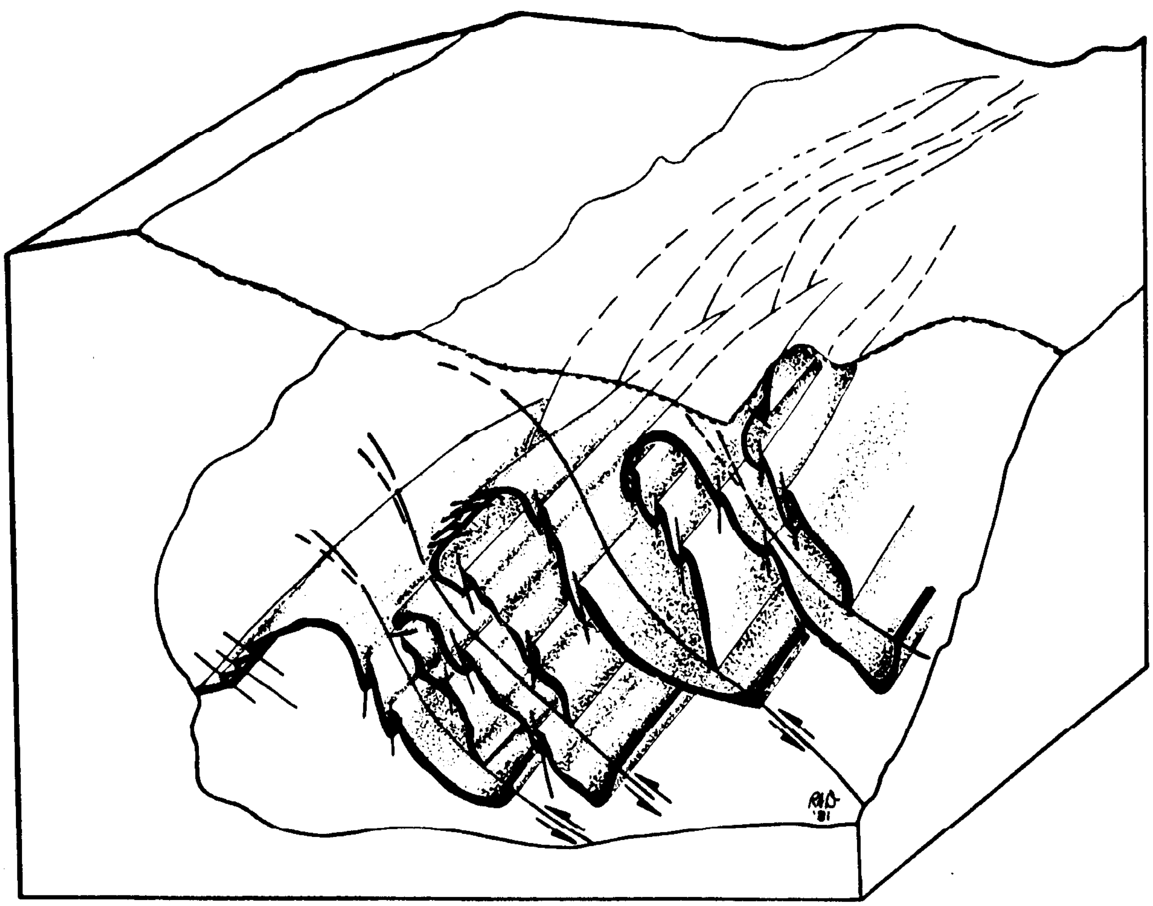
David H. Hight

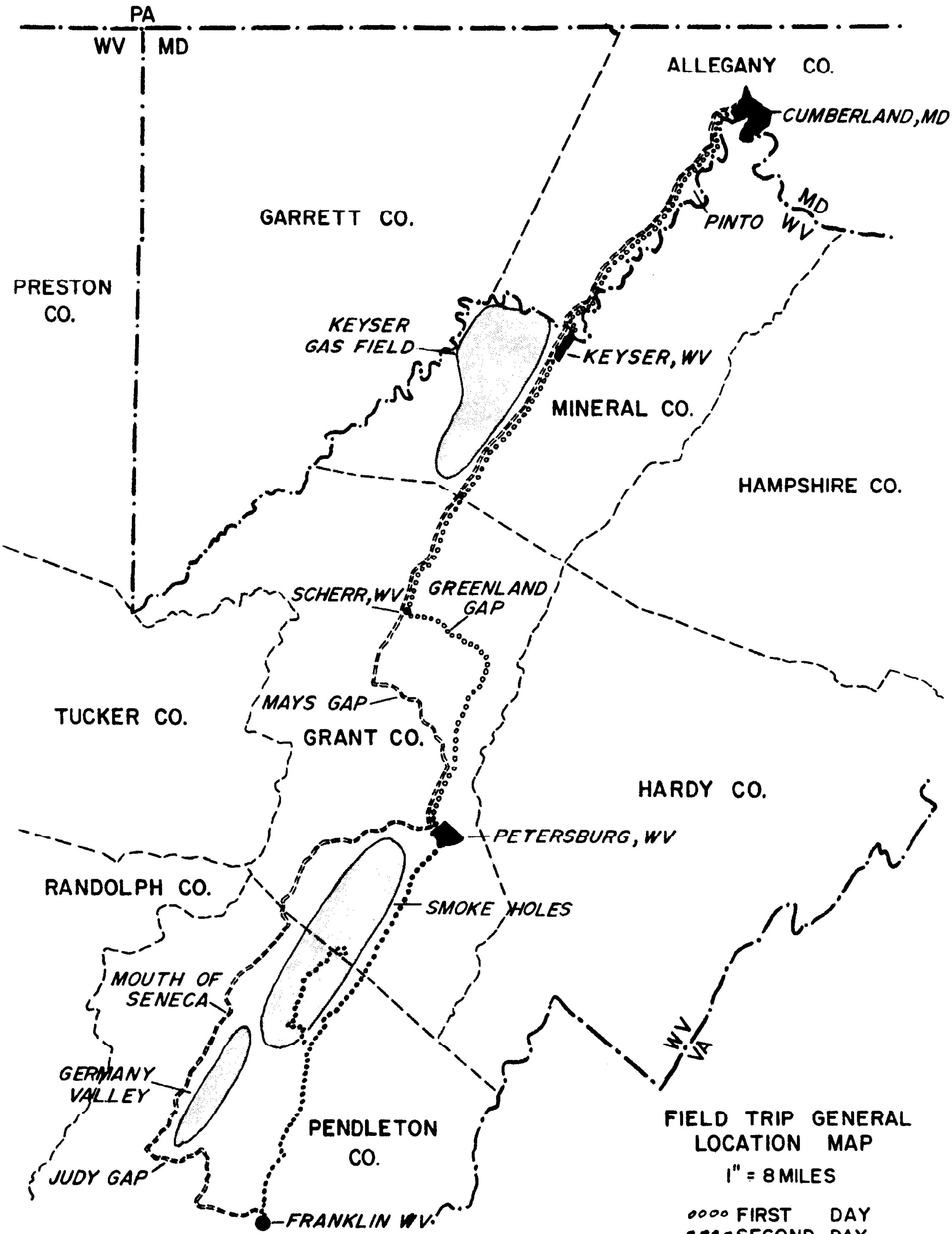
David H. Hight, President
Appalachian Geological Society

WELCOME

TO THE

EASTERN OVERTHRUST BELT





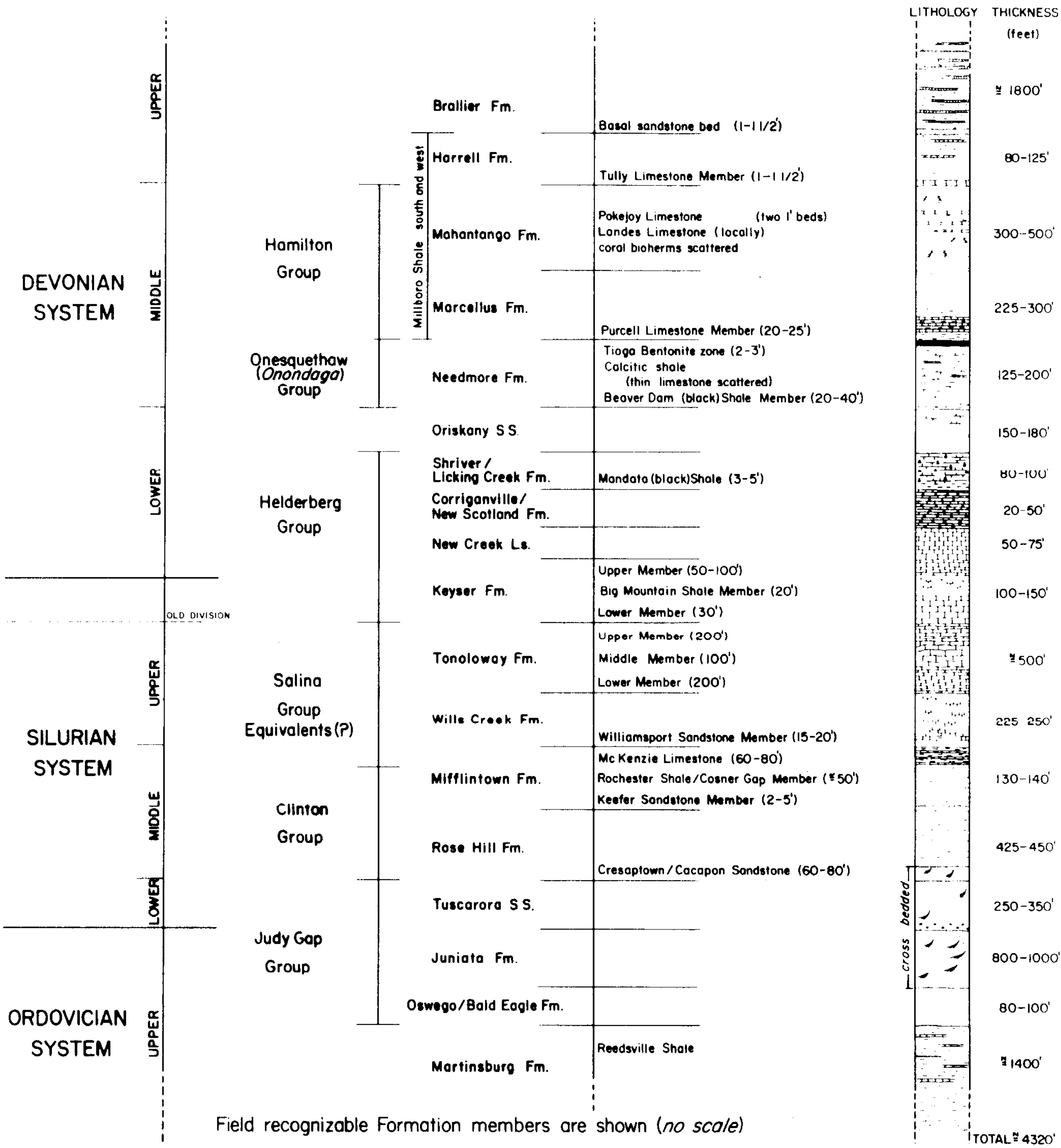
FIELD TRIP GENERAL LOCATION MAP

1" = 8 MILES

(NOTE: See daily maps for stop locations)

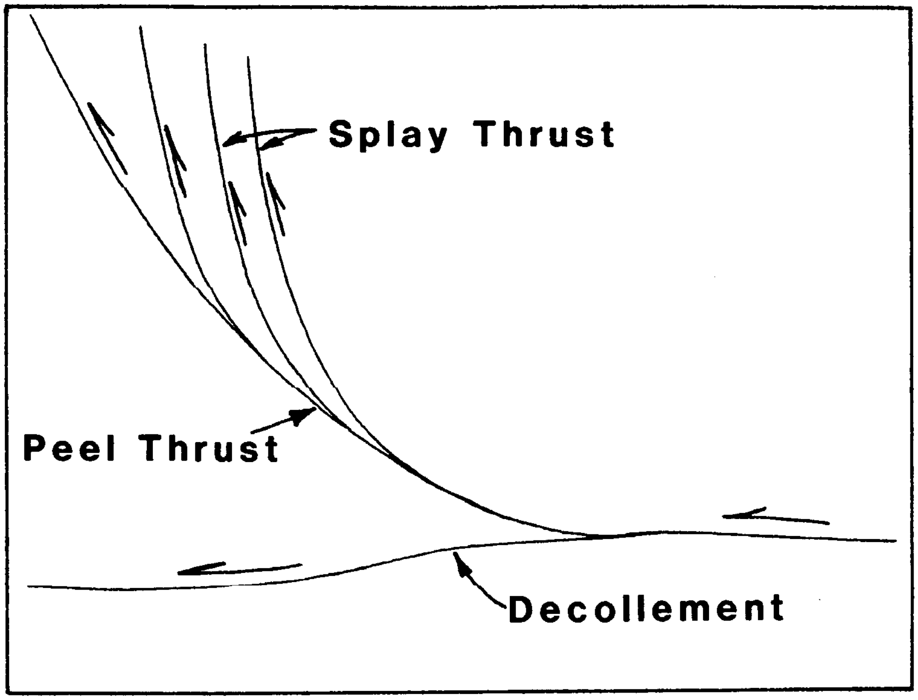
RAD, 1981

STRATIGRAPHIC COLUMNAR SECTION OF EXPOSED MAPPABLE GROUPS AND FORMATIONS

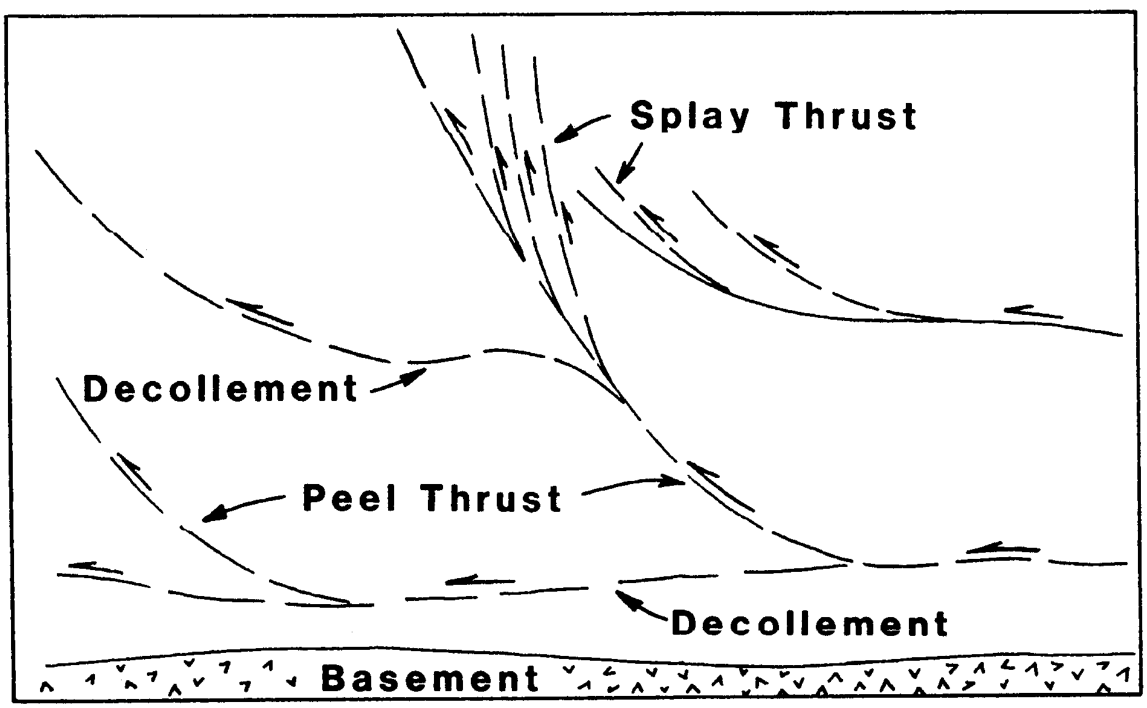


Field recognizable Formation members are shown (*no scale*)

TERMINOLOGY



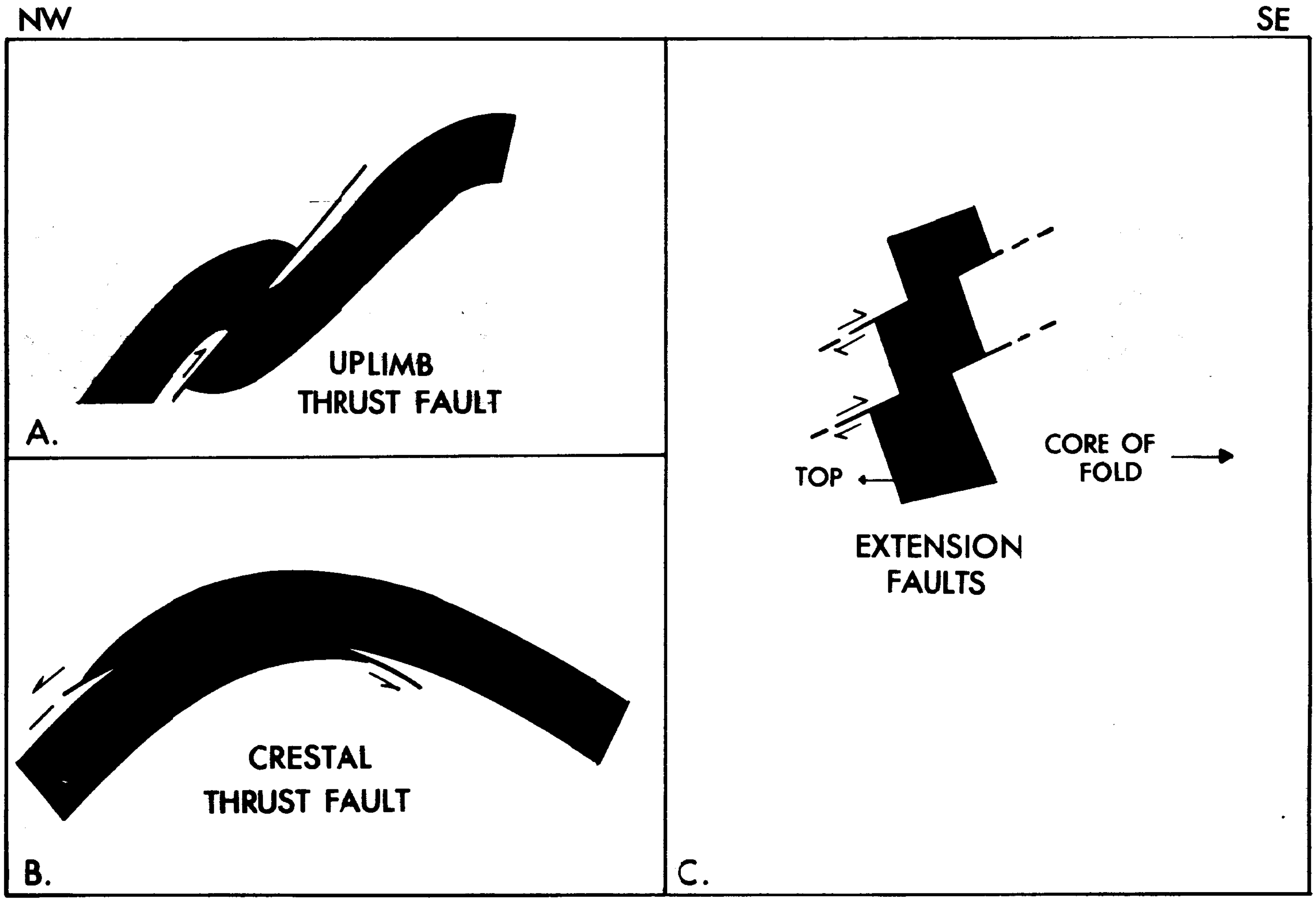
Schematic Diagram Showing The Origin Of Splay Thrust



Schematic Diagram Showing The Origin Of Low Angle Thrust Faults

(Rowlands and Kanes, 1972; reprinted from WV Geological Survey Misc. publ. "Appalachian Structures").

TERMINOLOGY



Three types of mesoscopic faults, found in the area, all of which are fold-related. Uplimb faults originated as northwest-dipping thrust faults on northwestern anticlinal limbs and southeast-dipping thrust faults on southeastern anticlinal limbs. Uplimb faults are the concentric faults of Gwinn (1970) and Perry (1975). (Perry, 1978; reprinted from WV Geological Survey RI No. 32)

Depositional And Deformational History of The Appalachian Basin

By

Richard W. Beardsley, Chief Geophysicist
Columbia Gas Transmission Corporation

Introduction

The present stratigraphic and structural configuration of the Appalachian Basin precludes its reconstruction using any singular basinal model. The purpose of this paper is not to address any individual structural or stratigraphic anomaly extant in the Appalachian Basin but, rather to provide a broad overview of the basin to yield enlightenment for further work. This paper may aid in understanding stratigraphic and structural complexities encountered on the field trip at hand through the discussion of pre-Alleghenian deposition and deformation. Grenville to Triassic time will be discussed with the amount of detail given to each deformation - depositional cycle varying proportionately as my experience justifies. This report is vastly simplified.

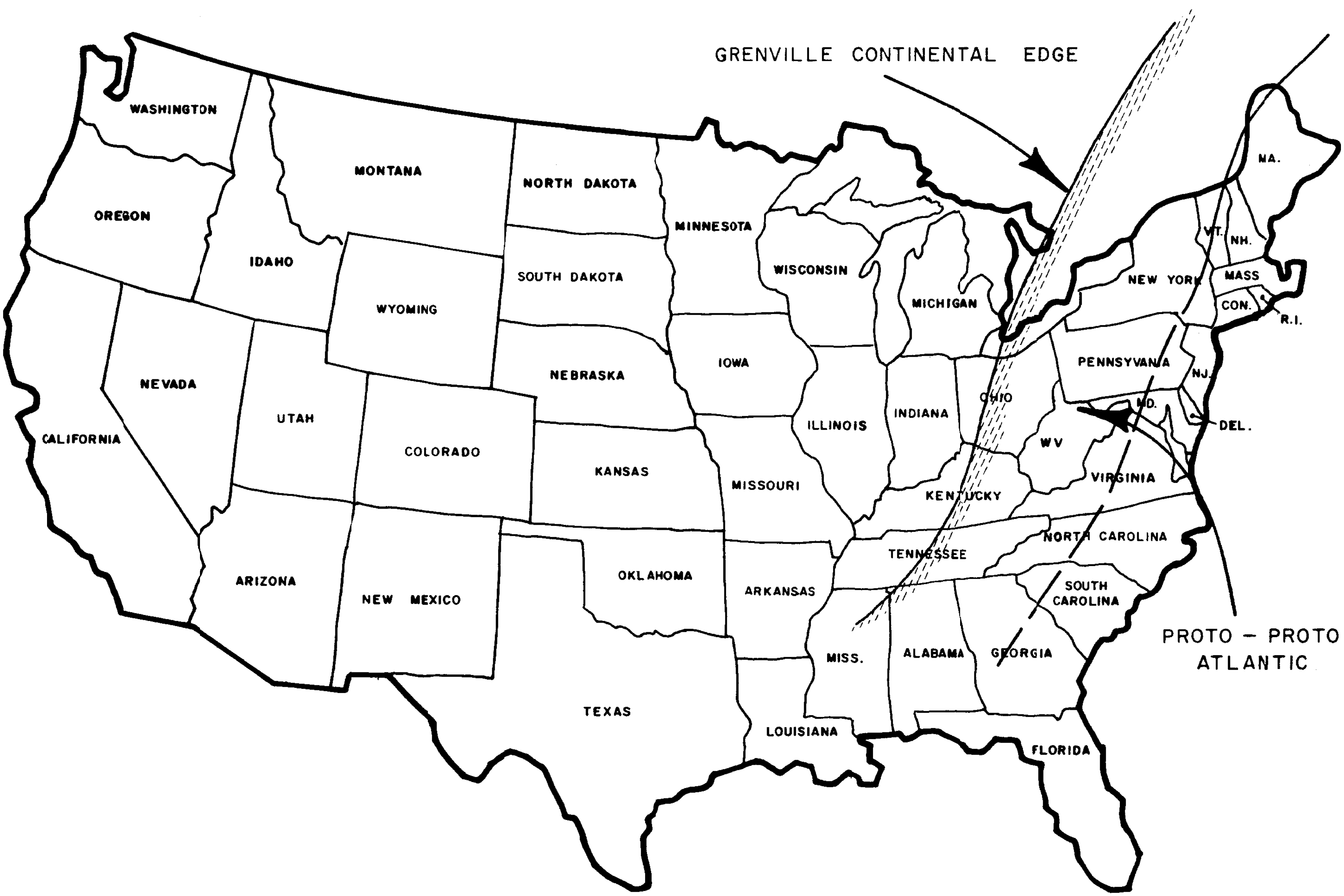
The data base for this report is developed from seismic data, well data, and surface geology over the entire Appalachian Basin with the exception of the Reading Prong area of southeastern Pennsylvania. The basic orogenic model presented is one of separation, deposition, collision, accretion, erosion and separation.

The Precambrian Grenville

Grenvillian deformation is of critical interest in the understanding of the Appalachian Basin. Unfortunately, very little is known about these metasediments in the subsurface. Stratigraphic knowledge of these rocks, is nebulous to non-existant based on a few wells which penetrated a few feet of this metasedimentary province. Seismic indicates the Grenville, and possibly pre-Grenville metasediments are extremely thick in the Appalachian Basin, and probably were to be deposited over both continental and oceanic crust along the edge of a proto-proto-Atlantic Ocean basin in pericontinental seas (Figure 1). Collision and subsequent closing of this oceanic basin caused massive deformation, which is characterized by low angle thrusting (Figure 2 & Section 1) which covers virtually all of the Appalachian Basin. Rejuvenation of these thrusts would subsequently influence all younger deposition/deformation in the basin. A large accreted wedge of sediments (Grenville) was emplaced during Late Precambrian and subsequent Early Cambrian rifting moved the new shoreline to the east, proximal to the Little North Mountain fault, Martic line and Logan's line area.

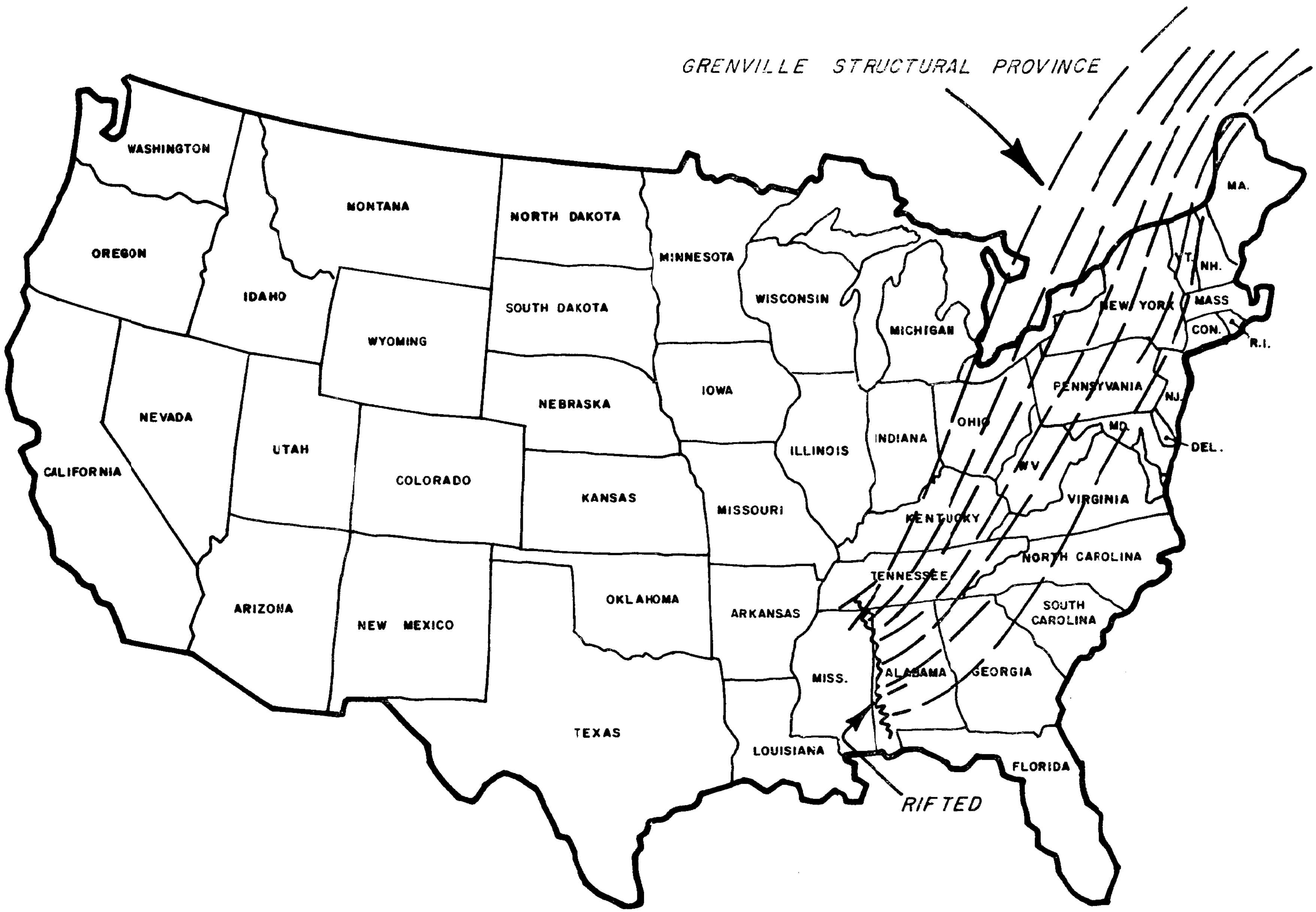
Cambrian Deposition

As the new oceanic basin formed to the east of the old Grenville shoreline (proto-Atlantic, Iaepetus), the huge chain of mountains formed during the Grenville Orogeny were eroded, reworked and subsequently peneplained. As a result, vast volumes of clastics were deposited in the active oceanic basin forming to the east (Figure 3 & Section 2) These clastics comprise the Chilhowee Group, whose thickness exceeds the total Paleozoic column in the



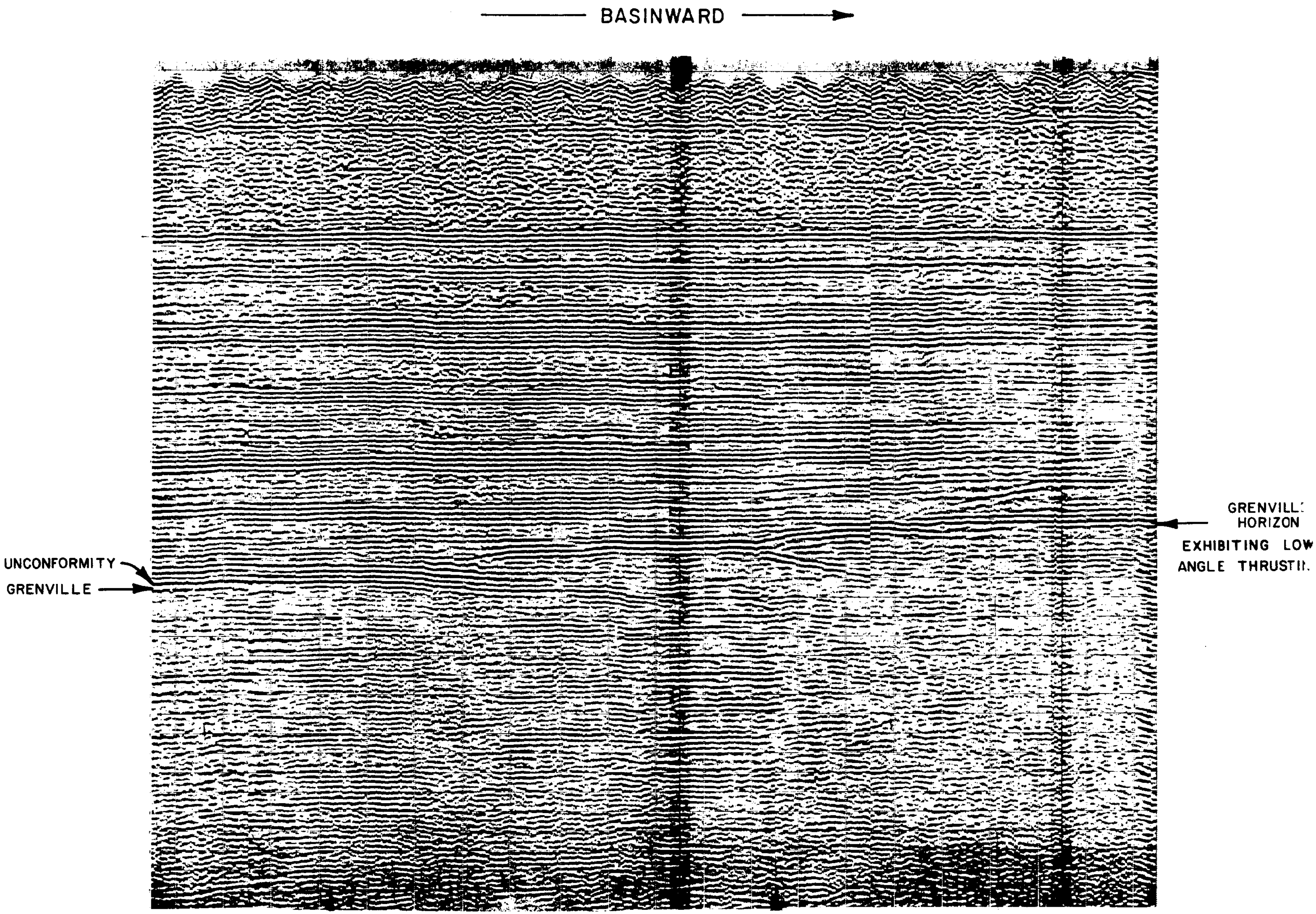
GRENVILLE CONTINENTAL SHELF EDGE

FIG. I

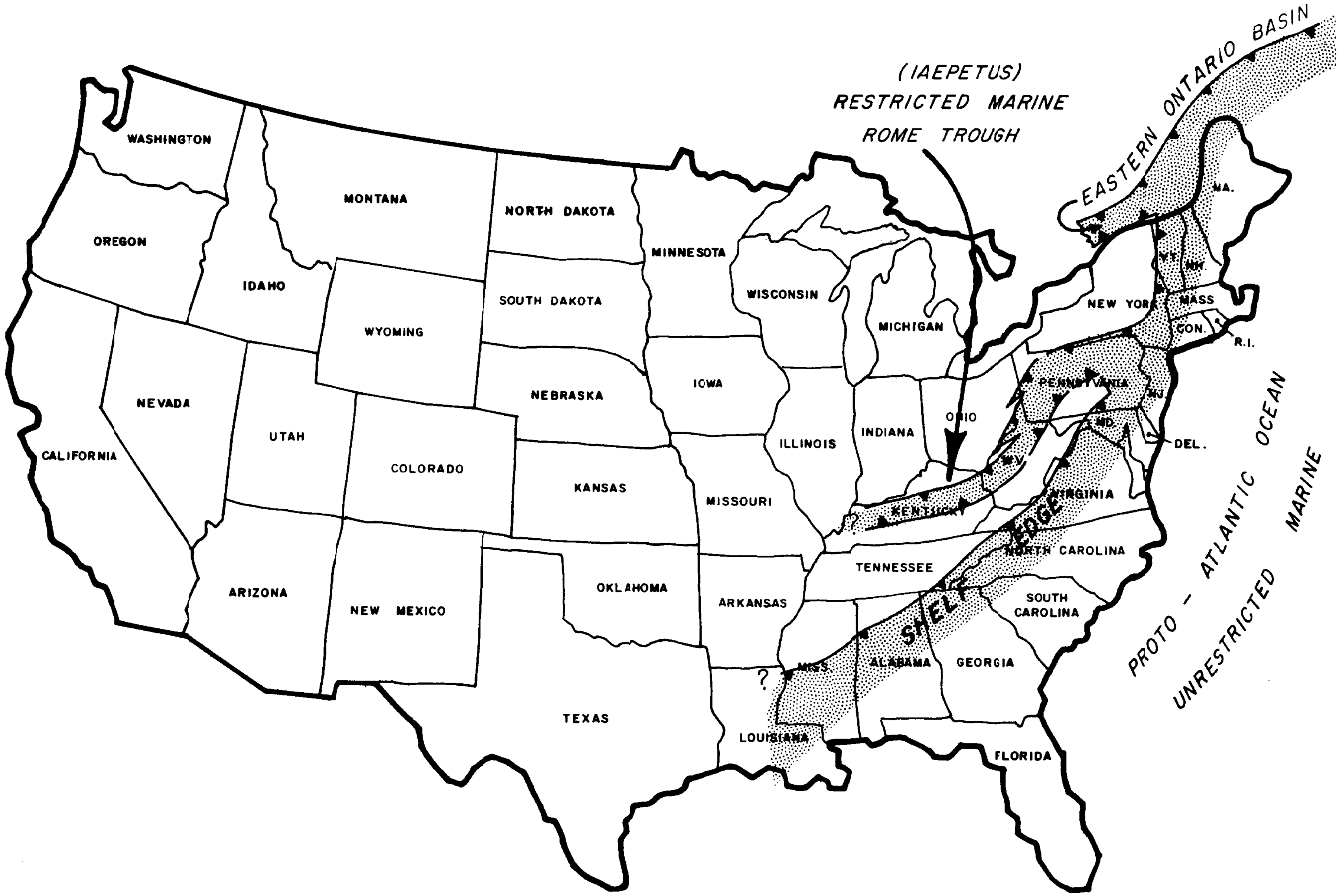


GRENVILLE STRUCTURAL PROVINCE

FIG. 2

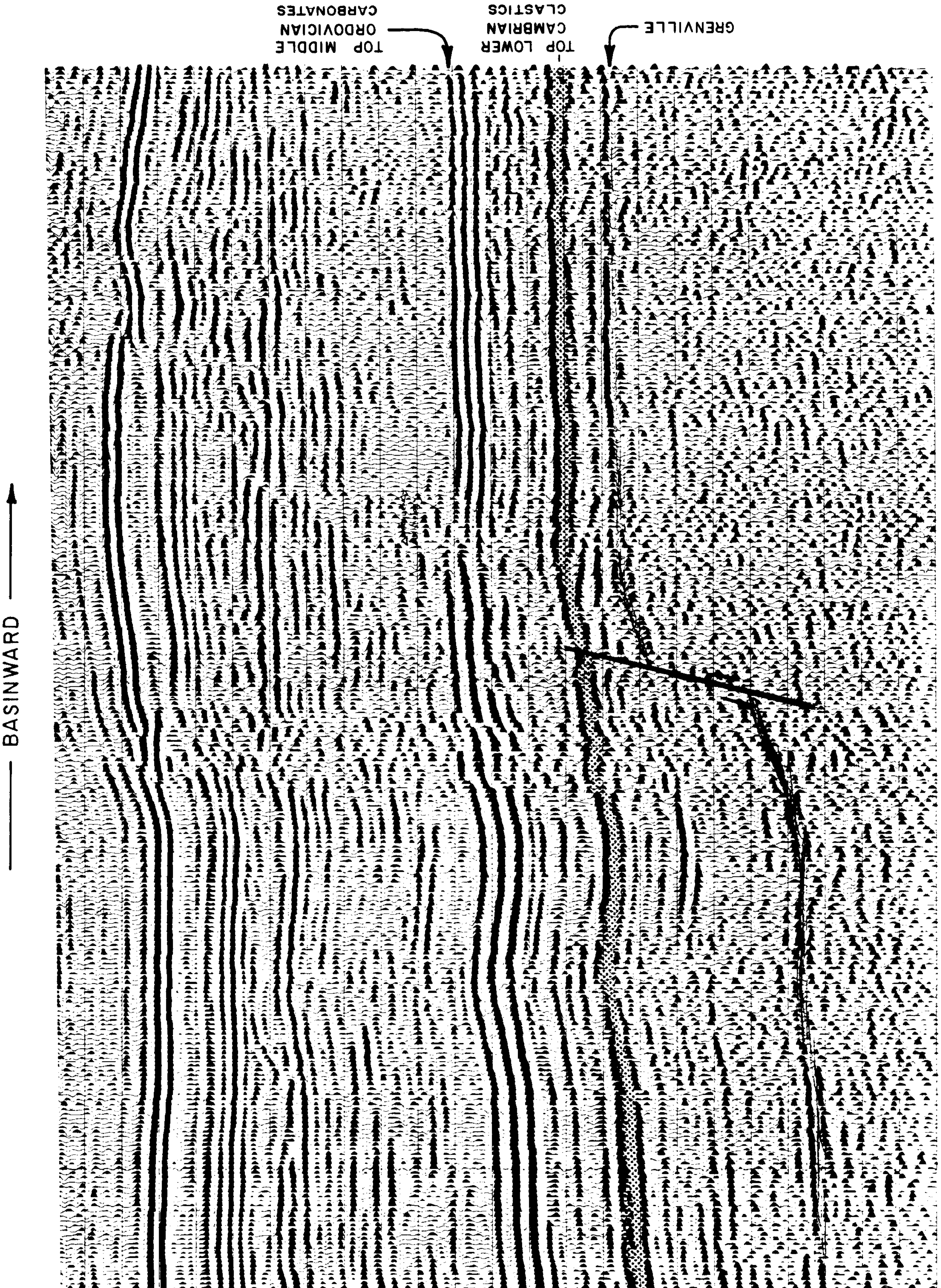

BASINWARD
UNCONFORMITY
GRENVILLE
GRENVILL
HORIZON
EXHIBITING LOW
ANGLE THRUSTI

SECTION I



CAMBRIAN MIDDLE ORDOVICIAN SHELF EDGE

FIG. 3


TOP MIDDLE ORDOVICIAN CARBONATES
TOP LOWER CAMBRIAN CLASTICS
GRENVILLE
BASINWARD

SECTION 2

rest of the basin. Localized subsidence (rifting) occurred in several areas of the basin with the termination of the erosional/ depositional clastic cycle. These downwarps and rifts occurred along Grenvillian thrusts whose relative displacement was reversed through tensional strain, resulting in high angle growth faults in the younger sedimentary sequence (Sections 2 & 3).

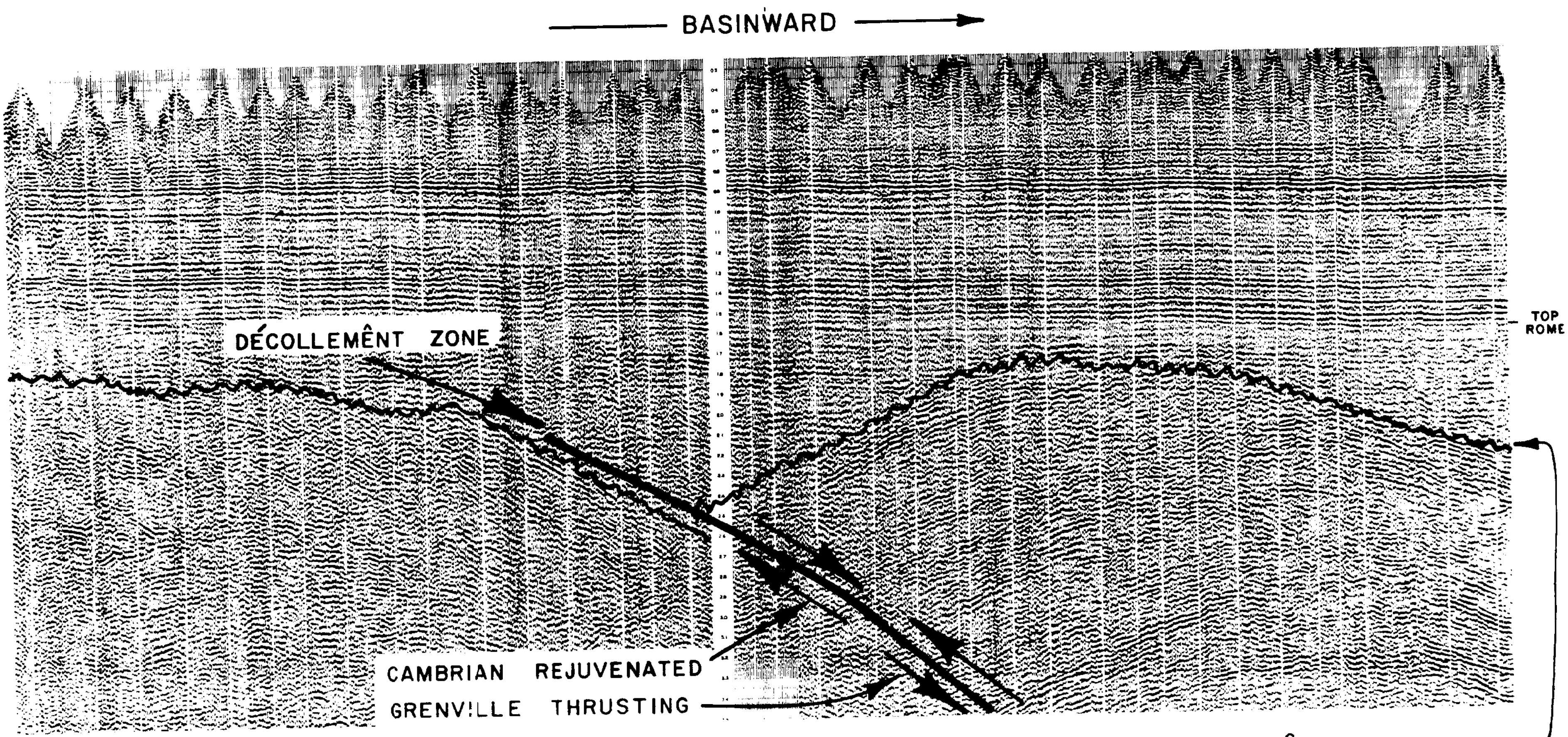
Source areas for Cambrian clastic influx were apparently limited by emergent Grenvillian topographic features. The proto-Atlantic may have been narrow enough to have a sedimentary mix from both continental massifs early in the Cambrian, but separated to such an extent that mixing was not present lithologically or faunally by the time the lower Middle Ordovician was deposited.

Apparent source areas for this Cambrian clastic influx are probable paleo-highs in the area of the Adirondacks, the Canadian shield (both in the Grenville and Superior Provinces), a mid-basin Precambrian horst feature, and residual Grenville highs in the vicinity of the Reading Prong, Great South Mountain, Fincastle, Virginia, and the Great Smoke Mountains (Figure 4).

The majority of deposition occurred in a restricted shallow marine environment. However, an area east of the old Grenvillian forelands was open water marine and possibly connected with the interior basin through the area of the Reading Prong (Figure 5). This configuration was consistent through Beekmantown deposition with minor tectonism occurring through extension along pre-existing Grenvillian fault zones.

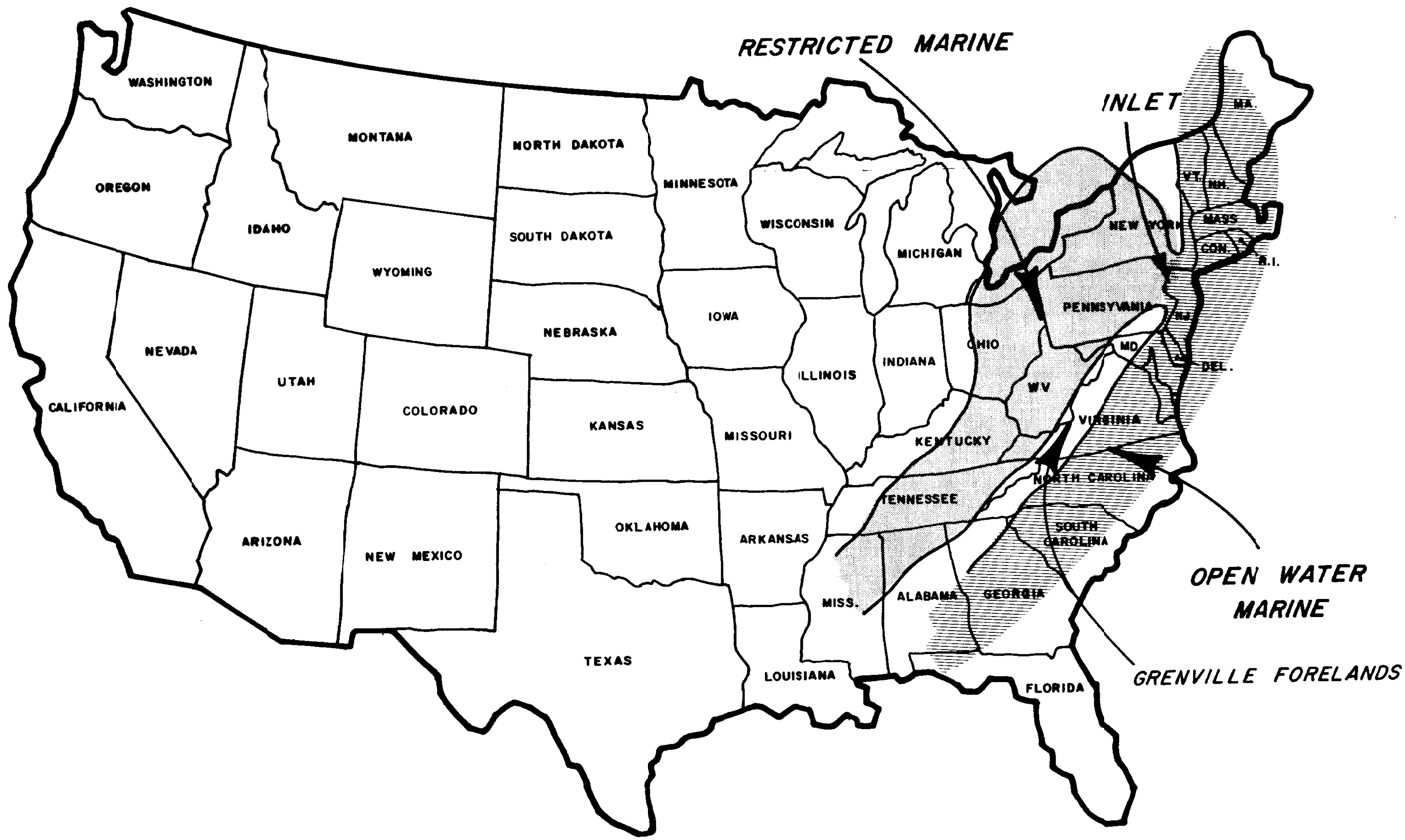
Major regression occurred at the end of Beekmantown time and

REJUVENATED GRENVILLE THRUSTS OVERLAIN BY CAMBRIAN CLASTIC WEDGES



SECTION 3

CAMBRIAN CLASTIC SOURCES
FIG. 4



CAMBRIAN SEAS

FIG. 5

a sequence of low lying ridges was formed along resistant members of the Beekmantown Group and along pre-existing fracture zones. A series of subsequent and consequent drainage patterns, with localized karst topography developed on this surface. The resultant dip after this major erosional event (creating the Cambro-Ordovician unconformity) was about 50 ft/mile oriented nearly parallel to the present regional dips in the Appalachian Basin. The deeper portion of the basin was probably not subject to sub-aerial erosion at the end of Beekmantown time (Figure 6).

The Ordovician

The Ordovician seas gradually transgressed across the Cambro-Ordovician unconformity. Two intermittently emergent high areas restricted water circulation and were very abundant in marine fauna; the Algonquin-Cincinnati Arch complex to the west and a partially rejuvenated Grenvillian Foreland to the east (Figure 7). Clastic influx during Early Ordovician deposition only occurred near, still emergent Grenville highs (Figure 5). Deposition was fairly uniform until the end of Black River deposition when the Taconic Orogeny altered the basin configuration. Major basinal extension features developed preceding the Taconic Orogeny. Major faults (both growth and transcurrent) were reactivated. The central portion of the pre-Taconic basin was oriented approximately N 35° W through the corner of Delaware, New Jersey, and Pennsylvania borders. The basin steps up across growth faults to the northeast, southwest and northwest (Figure 8). At this time, the Austin Glen

AREA OF NO CAMBRIAN ORDOVICIAN UNCONFORMITY

FIG. 6

TOPOGRAPHIC HIGHS DURING ORDOVICIAN DEPOSITION

FIG. 7

PRE - TACONIC EXTENSION FEATURES
AND
BASIN CONFIGURATION
FIG. 8

greywacke, Trenton limestone and Martinsburg-Utica-Reedsville-Sequatchie shales were being deposited concurrently across the basin. This was the period of maximum extension of the proto-Atlantic which would start to close at the end of Trenton deposition.

As the proto-Atlantic closed, many new Taconic thrust sheets developed which ramped upward along old Grenvillian decollement surfaces forming new decollement zones syndepositionally with the Middle Ordovician shales. A large thrusted foreland region was formed to the east which acted as a source area for subsequent Silurian and Devonian clastic deposition (Figure 9). Many tectonic breccias (Max Meadows, et al) were formed as the thrust ramped up through the already lithified Cambrian-Middle Ordovician carbonates to the west. Nappe features (Great South Mountain) were formed of abyssal marine sediments to the east.

Silurian

After the initial impact of two continental masses causing the Taconic Orogeny, clastics were shed from the resulting mountain chain both to the east and west of the foreland core as it eroded. Most of the area presently east of the Little Mountain fault, Martic line, and Logan's line received no sediments, with the exception of a few low-lying areas such as the present Massanutten Syncline and the northeastern coastal regions. Silurian and Devonian clastic influx into the now restricted Appalachian Basin had multiple source areas (Figure 10).

EMERGENT TACONIC FORELAND REGION

FIG. 9

SILURIAN & DEVONIAN
CLASTIC SOURCE AREAS
ALONG FORELAND BELT
FIG. 10

The Clinton-Medina was derived from a northerly source and the Tuscarora from the newly formed mountains to the east. We find the clastic ratios in the Lower Devonian-Silurian groups increase dramatically toward the Taconic range.

Sediment influx slowed during Middle to Upper Silurian time and the restricted basin was flattened as salt, anhydrite, and dolomite smoothed over pre-existing anticlinal, synclinal, monoclinal and fault related features. Regional dip at the end of Salina deposition was probably less than 50 ft/mile.

Devonian

The Lower Devonian was probably deposited as a precursor to the Acadian Orogeny. A large part of the basin was subject to flow features in the thicker salt units in the Salina. Salt pods developed creating topographic highs. Clastic influx skirted these features. As further flooding of basin occurred, Onondaga carbonate mounds developed on some of the salt highs. These highs may have only varied a few meters in elevation from the surrounding water depth. As the waters continued to deepen, some of these reefal mounds reached fairly large proportions. The Acadian Orogeny progressed, uplifting portions of the east central basin causing a large Upper Devonian clastic influx after the deposition of the Lower Devonian shale (Figure 11).

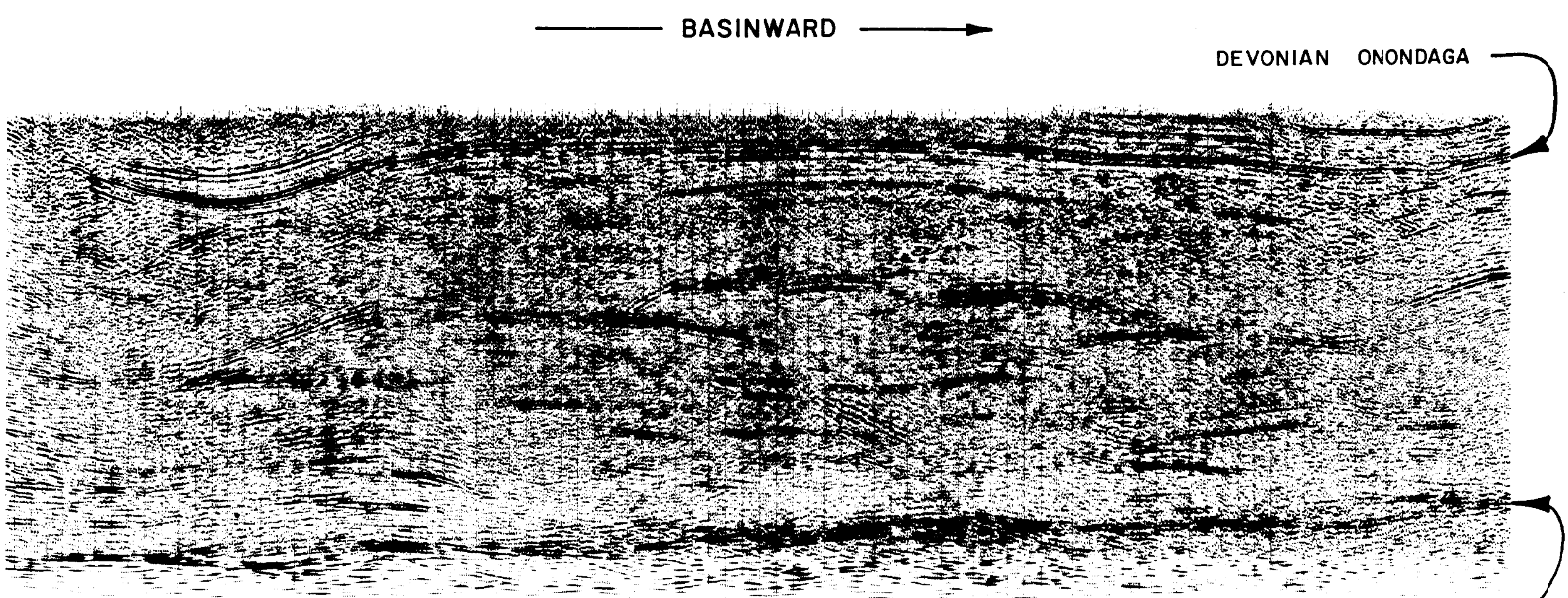
The Devonian clastics again skirted the topographic highs. Shallow water marine deposition with periodic clastic influx from post-Acadian - pre-Alleghenian tectonism prevailed as the continents (Laurasia & Gondwanaland) continued to bump and grind.

LATE ACADIAN CLASTIC SOURCE AREA

FIG. 11

Mississippian, Pennsylvanian and Triassic

Intermittent movement continued from the Acadian with many interruptions. During the Alleghenian, old thrusts were refolded and new thrusts were generated, ramping into and from decollement zones within the Waynesboro-Rome, Reedsville-Martinsburg-Sequatchie-Utica, the Salina Group, and the Devonian shale (Section 4). By the end of Pennsylvanian time, deformation and accretion from continental collision was completed and the present structural configuration of the Appalachians resulted. The various cycles of Paleozoic deposition and deformation had run their full course. The new basins formed during the Taconic were mechanical identities to the first basins formed after the Grenvillian structural retreat.



SECTION 4

FIRST DAY

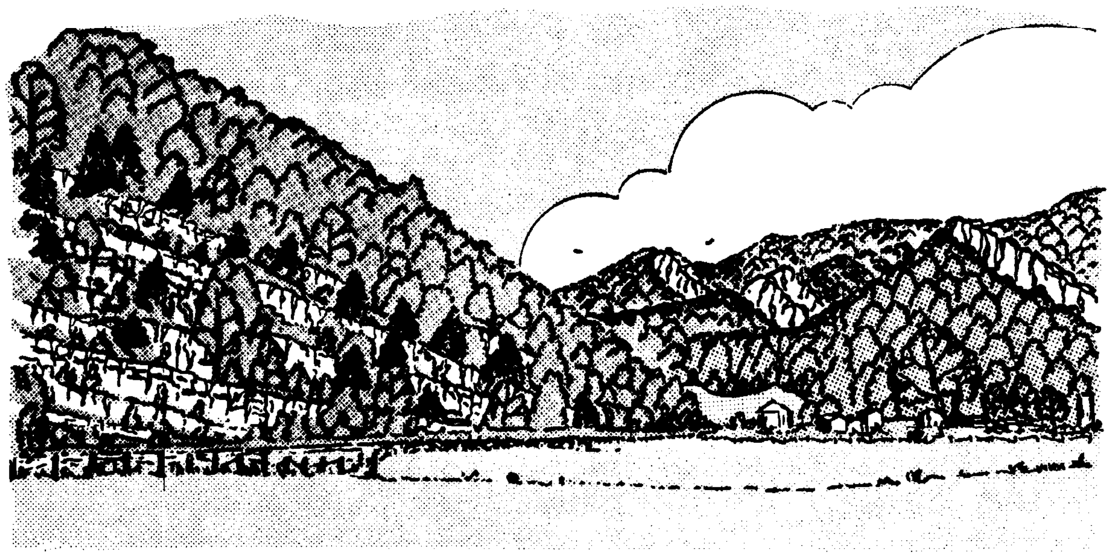
At length we came to the Knobley, which we ascended, passing through a hamlet scattered carelessly along the cultivated slopes of the mountain. Immediately beyond rises a bold and rugged mountain, whose craggy top is indented like the battlements of a castle, and whose sides sweep down, dark with firs and hemlocks, and every variety of pines, to the edge of the deep valley. Looking to the right, the mountains are broken and irregular, as if they had been tossed and torn to pieces by some mighty upheaving of the earth, and had thus fallen scattered about in confused, giant masses: some elegant and majestic as the "star'y-pointed pyramid;" some grand and massive as the "proud bulwark on the steep;" others of hugh, mishapen bulk. Between them we crossed, and decended by easy traverses to the other side. For a mile or so we *wound our way through the defiles of a broken range of hills, and emerged at length into a narrow and beautiful - picturesque valley - the Allegany piled up in grand masses on one side, and the road running for some miles along the banks of a clear rapid stream, known herabouts as New Creek.*

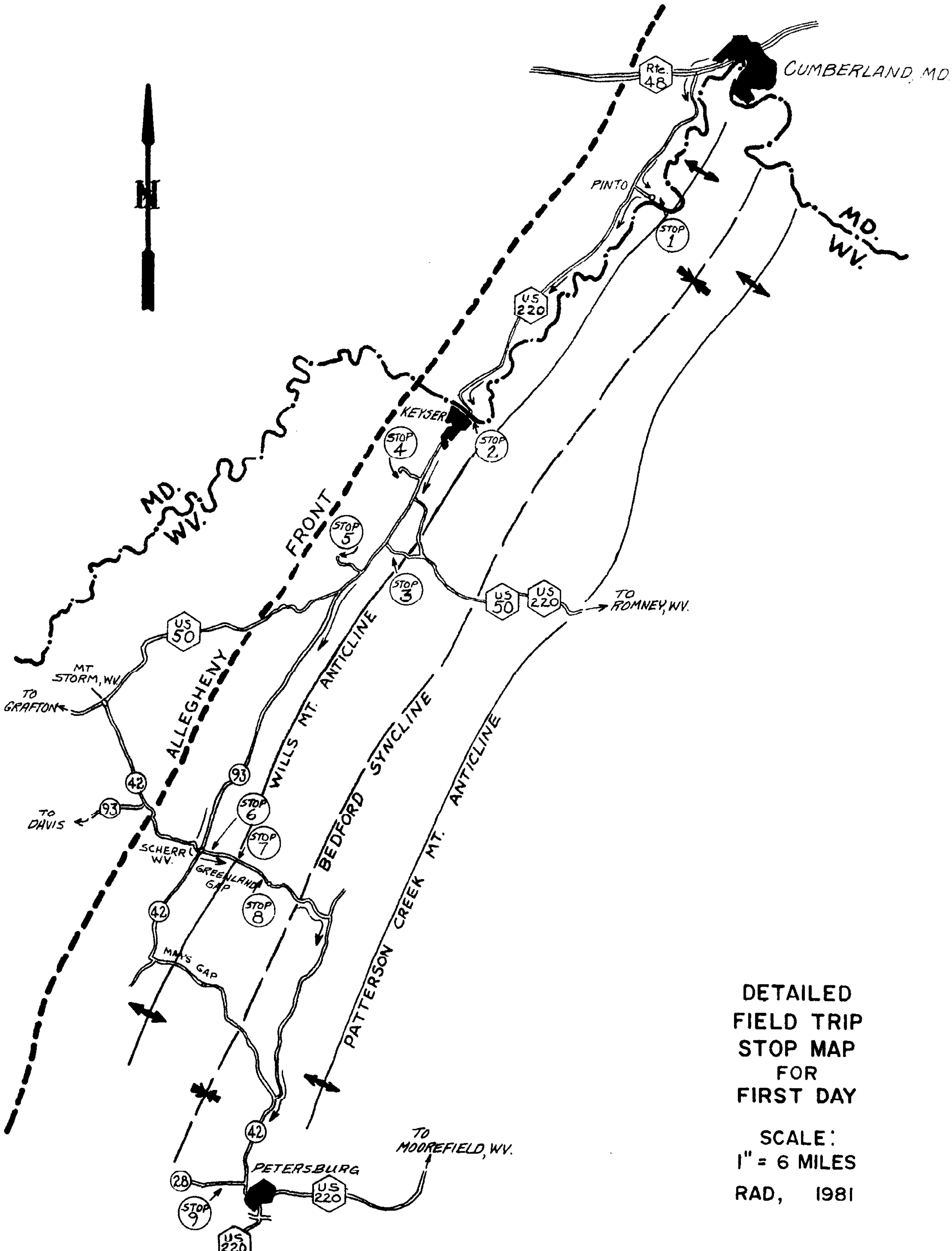
by

"The Clerke of Oxenforde"

The Blackwater Chronicle

1853





DETAILED FIELD TRIP STOP MAP FOR FIRST DAY

SCALE: 1" = 6 MILES

RAD, 1981

STOP 1. PINTO RAILROAD CUT

This stop is a particularly fine exposure of the entire Silurian carbonate sequence with many structural overtones. Structurally, the exposure is along the vertical to overturned northwest limb of the Wills Mountain anticline (Figure 1). There are some pre-Wills Mountain shear zones exposed which can be separated from those features coeval with the Wills Mountain anticlines and those post-Wills Mountain structures.

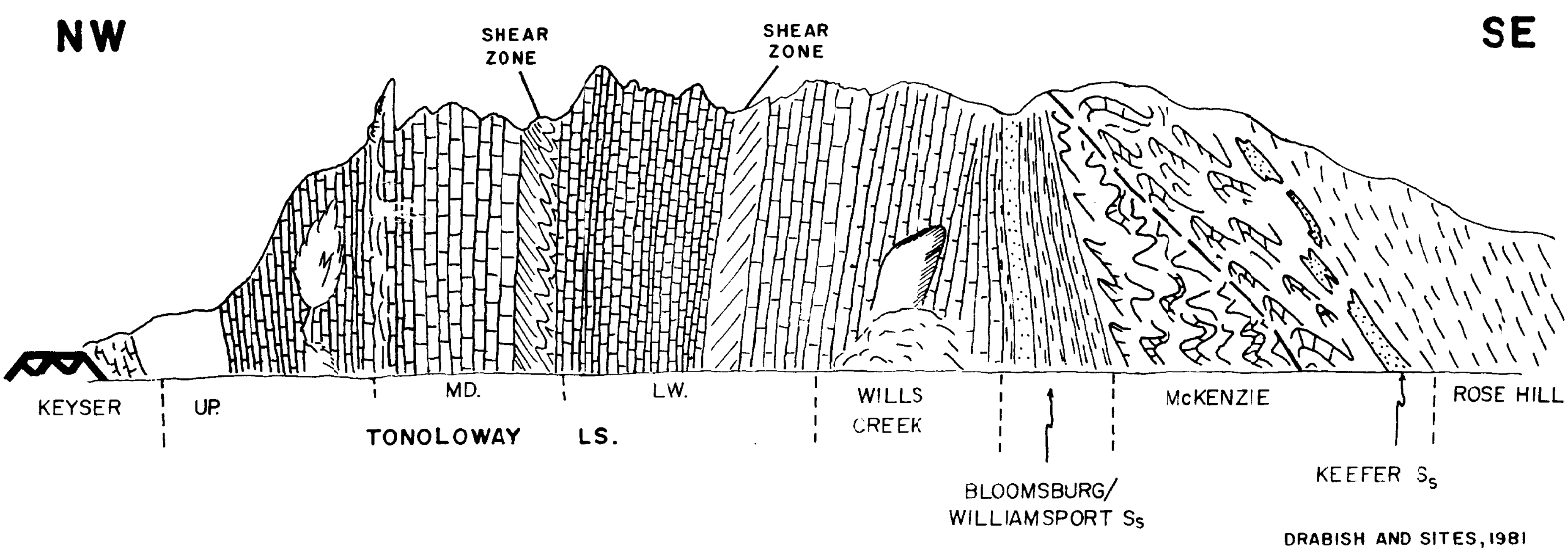
Progressing eastward along the tracks toward the core of the anticline, the bedding orientations range from overturned to vertical and back again to overturned. The core of the fold is not observed at this particular stop. The entire anticlinal crest has been eroded. As one approaches the crestal portion, localized Alpine-type deformation can be observed, i.e. refolded folds, chevron folds with sub-horizontal axial planes, near boudinage-like structures.

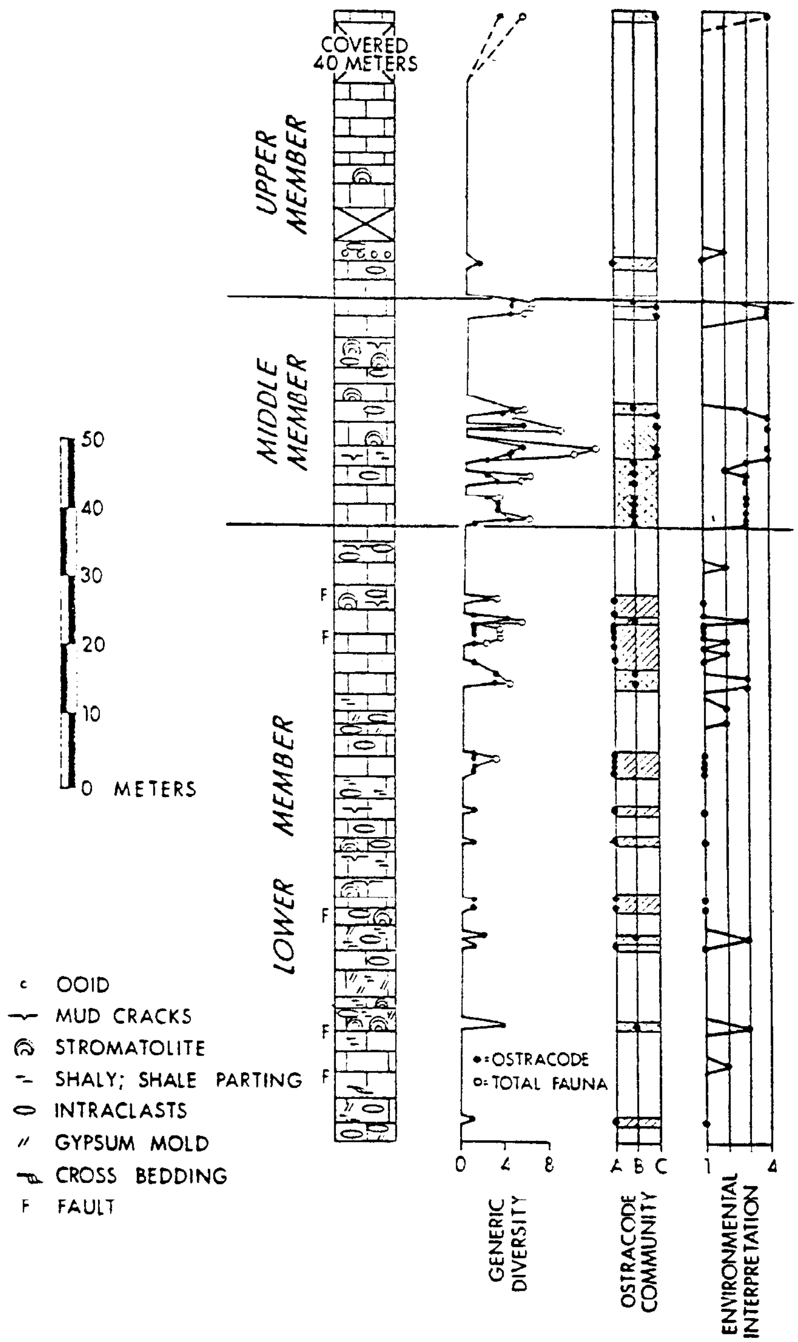
This exposure implies that regionally this is a smaller subsidiary anticline related to a much larger subsurface structure. The entire feature has been effected by much lateral movement from the southeast.

Stratigraphically, this is one of the finest Silurian carbonate exposures within the Central Appalachians. Interpretations by Smosna and Warshauer, 1979, of generic diversities and paleontological community groupings coupled with multivariate analysis of carbonate petrologies show a paleoenvironment differentiating a low tide to wave base energy system along a deeper subtidal to supratidal depositional gradient normal to the paleo shoreline (Figures 2,3 and 4).

GEOLOGIC PROFILE
ALONG RAILROAD TRACKS
AT
PINTO, MD.

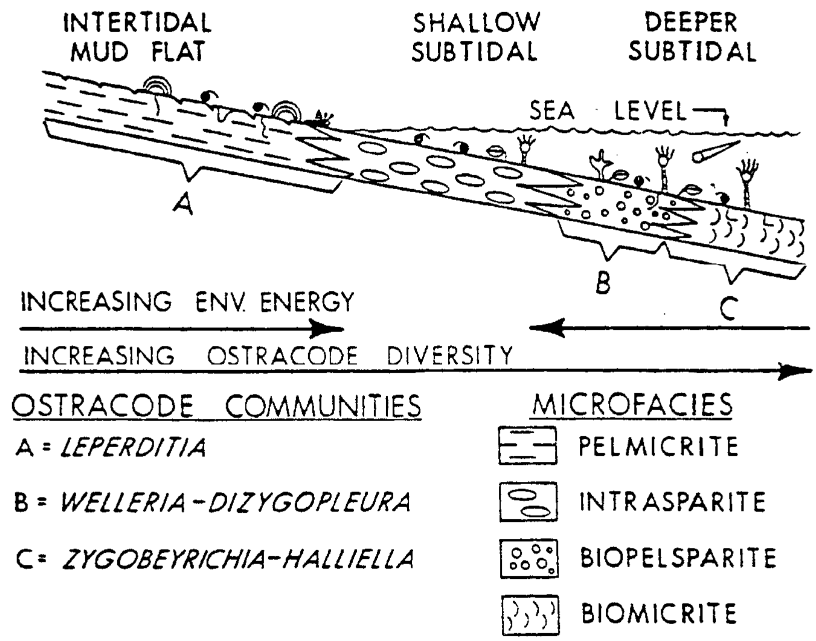
FIGURE I





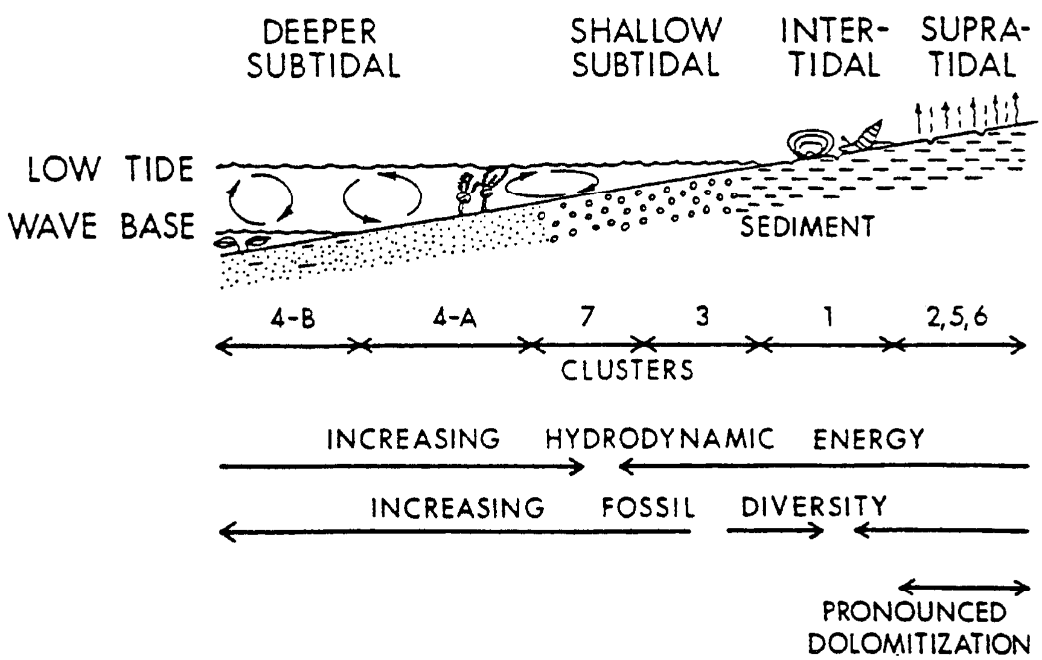
Diagrammatic stratigraphic section for the Tonoloway Limestone at Pinto. When the generic diversity of the ostracodes equals the generic diversity of the total fauna, only the ostracode value is shown. Ostracode community A = *Leperditia*, B = *Welleria-Dizygopleura*, C = *Zygobeyrichia-Halliella*. Environmental interpretation 1 = intertidal mudflat, 2 = shallow subtidal, 3 = deeper subtidal, 4 = deepest subtidal. (Warshauer & Smosna, 1977)

Figure 2



Diagrammatic interpretation of the lateral relationships of both the ostracode communities and carbonate microfacies. (Warshauer and Smosna, 1977)

Figure 3



Diagrammatic interpretation of the Tonoloway paleoenvironments. Plotted at the bottom of the diagram are the relative locations of the 7 Q-mode clusters and the important environmental gradients.
(Smosna and Warshauer, 1979)

Figure 4

STOP 2. QUEENS POINT FAULT

This exposure is the first Oriskany stop of the field trip. Not only is it the first locality where thrust faulting was observed and studied along the Appalachian Front (Dennison and Naegele, 1963), but it is also a hands-on look at the type of structural configuration that is presently envisioned to be present at 8000 feet under the Allegheny Frontal Zone (that area between the Allegheny Front and the northwest limb of Wills Mountain anticline).

The fault trace can be seen on the following geologic map of the Keyser area (Figure 5). On the surface it can be traced for only a short distance. The actual fault dips approximately 7 degrees to the northwest, and is exposed 100 feet above the railroad. The Oriskany exposure at the track level is the nearly vertical to overturned footwall block beneath the thrust (Figure 6). This is also an excellent exposure to observe the microfractures and slickensides present in the footwall block and their relationship to the overriding hanging wall. Frictional drag has produced severe overturning in the Needmore Shale beneath the exposed fault trace and should be noted.

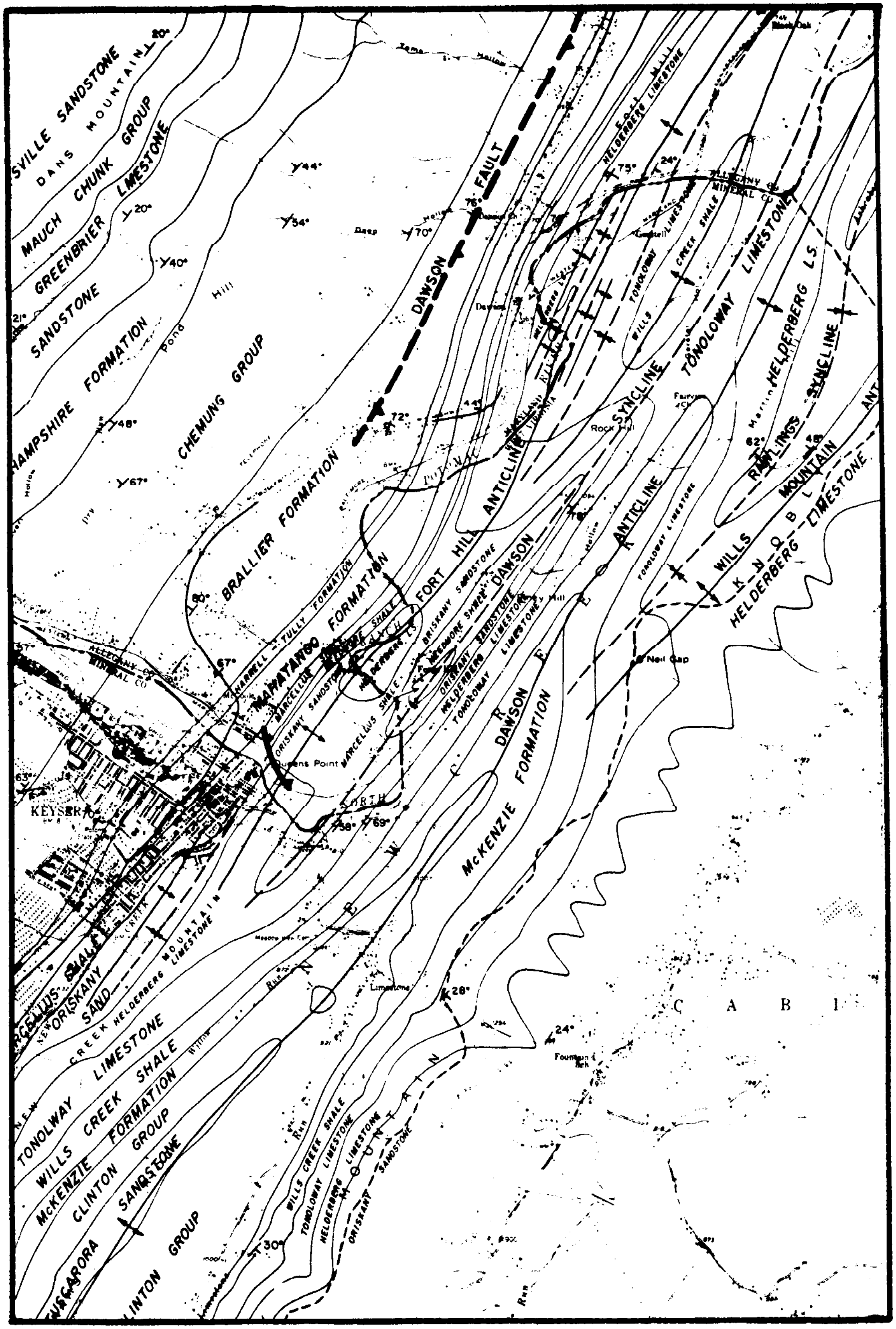
Depositional, stratigraphic and environmental relationships of the Oriskany Sandstone as a reservoir rock will be summarized now, so that, a basis for understanding the "nature of the beast" can be established early before the trip proceeds to additional Oriskany outcrops, etc.

The Oriskany Sandstone, throughout the Appalachian Basin represents the greatest departure from carbonate sedimentation since the Silurian clastic influx. Carbonate sedimentation never completely ceased when clastic influx started. Evidence for this is in the occurrence of quartz grains and sandy build-ups, as well as siltstone and shale interbeds, in the Upper Helderberg carbonates. This increase in clastics previews the arrival of the Oriskany Sandstone.

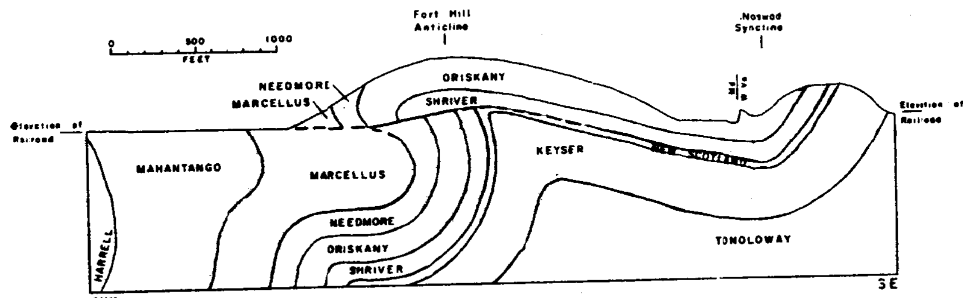
Very few characteristics of clastic deltaic sedimentation are preserved in any Oriskany deposits. Thus, it appears that subsequent reworking may have masked such characteristics. Process-response models similar to that used for Oriskany deposition require some kind of deltaic input to account for the large volume of sediments present. Oriskany sediment sources, as presently observed from field and detailed provenance studies indicate more than one source area.

Generally, the Oriskany Sandstone is a widespread unit having discrete sand bodies within the sediment package, with both depositional and mechanical processes controlling reservoir character. Various facis show enhanced permeability and porosity due to diagensis; whereas other facies are dirty and tightly cemented by calcite and silica cement. The Oriskany throughout its areal extent can be classified into three major lithologic types: they are, quartz arenites, calcareous sandstones and sandy limestones. Quartz arenite facies are most susceptible to fracturing, as well as other types of porosity. The other Oriskany lithogies are composed of more carbonate material thus increasing ductility and decreasing fracturing and porosity. The position of each lithofacies within the vertical sequence changes throughout Oriskany time, as reflected across the eastern counties of West Virginia. The most desirable lithofacies (quartz arenite), therefore, may be developed in a lower, middle or upper position within the Oriskany. As a result, the best reservoirs commonly are separated in vertical sequence.

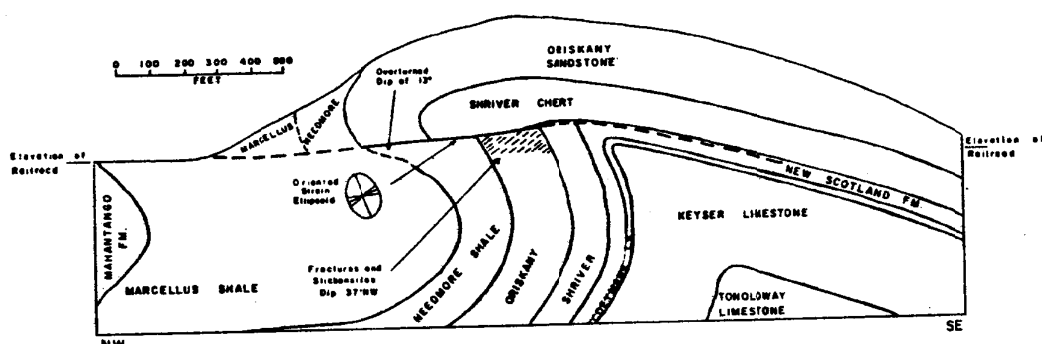
Later in the morning at the Mastellar No. 1 well (Stop 4), the significance of the structural setting of the developed Queen's Point structure can be observed, as can most of the surface structures of this area.



Geologic Map Of Keyser Area
1" = 4000'
(Modified from Dennison, 1963)
Figure 5



A.- SETTING OF QUEENS POINT FAULT



B.- DETAILS OF QUEENS POINT FAULT

CROSS SECTION OF QUEENS POINT FAULT
(DENNISON AND NAEGELE, 1963, REPRINTED FROM WV
GEOLOGICAL SURVEY BULLETIN NO. 24)

Figure 6

STOP 3. NEW CREEK QUARRY

New Creek quarry is an excellent exposure for observing a number of important stratigraphic and structural features as they relate to the Upper Silurian and Lower Devonian age rocks (Figure 7). Head (1969) describes the stratigraphic section of Keyser Limestone within this quarry. His section illustrates a vertical succession of sedimentary environments whose changing nature reflects various stages of regional carbonate depositional basin evolution (Figure 8). The following is a measured and described stratigraphic section by Head, 1969, which is exposed in the New Creek quarry.

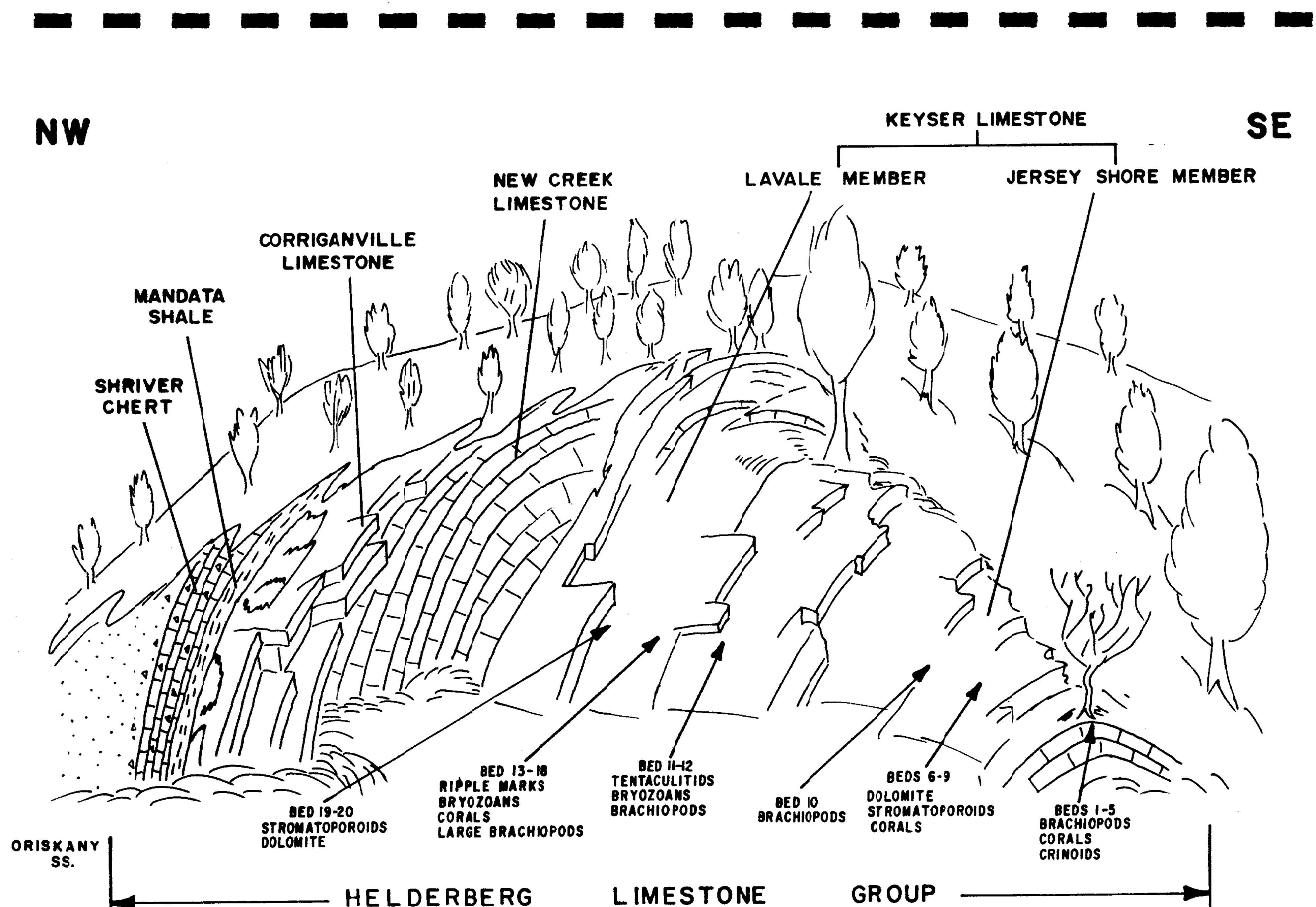
	Stratigraphic Thickness Bed (Feet)	Total
Keyser Limestone		
LaVale Limestone Member		
20. Dolomitic limestone and limestone, finely laminated with occasional fossil fragments and "birds eye" structures. Generally unfossiliferous. Upper contact sharp and erosional................................	3.5	133.7
19. Limestone and dolomitic limestone. Upper 2' thin bedded and laminated. Stromatoporoid bed 2-2.5' from top. Laminated and interbedded fossil fragmental limestone 2.5-4'. Unfossiliferous laminated dolomitic limestone 4-10.5'	10.5	130.2
18. Limestone, thin to medium bedded 2-6". Very coarse grained calcarenite with dominantly angular fossil fragments interbedded with unfossiliferous laminated limestone......	11.0	119.7
17. Limestone, laminated calcisiltite with occasional coarse grained interbeds, chert. Scour and fill and ripple marks. Occasional fossils................................	20.0	108.7
Jersey Shore Limestone Member		
16. Limestone, thin-bedded, argillaceous, weathers somewhat nodular........................	4.0	88.7

		Stratigraphic Thickness Bed (Feet)	Total
15.	Limestone, fine grained, finely laminated, sometimes cross-laminated; burrowed, sparse fauna...............	3.5	84.7
14.	Limestone and shale. Knobbly, medium and coarsely crystalline limestone interbedded with dark gray shale and shaly limestone. Burrowed, brachiopod rich. Main east wall of quarry within this unit. Very distinct 5" bed of cherty calcarenite at top of this unit. Bed is gray with 1" vertical brown burrows extending downwards.	4.5	81.2
13.	Limestone, medium to thick bedded, very coarsely crystalline, very fossiliferous. Coquina of brachiopods, bryozoans and corals. Decrease of fossil size and grain size upwards..........................	5.5	76.7
12.	Shale and shaly limestone interbedded with lenses, beds, and nodules of limestone. Profusely burrowed, tentaculitids......	6.0	71.2
11.	Shale, dark gray, calcareous, interbedded with light gray nodular limestone. Bryozoans and brachipods abundant................	5.5	65.2
10.	Limestone, fine fossil hash, silt, and sand with argillaceous material admixed by burrowing. Abundant brachiopods.........	5.5	59.7
9.	Dolomitic limestone and dolomite, weathers light brown. Upper surface uneven and appears to be erosional. Some tentaculitids; 3" gastropod near base; 1.5-2' thick. Stromatoparoid bed-favositids and rugose corals; bedding draped over top of stroms., ostracods, coenites; 5-1' thick at base of this unit...	2.5	54.2
8.	Limestone, medium bedded, medium grained, fossiliferous.............................	9.2	51.7
7.	Shale, calcereous, surrounding slightly nodular limestone bed.......................	0.3	42.5
6.	Limestone, medium grained, medium bedded, fossiliferous.............................	2.3	42.2
5.	Limestone, medium grained, medium bedded, fossiliferous.............................	7.0	39.9
4.	Shale and shaly limestone. Thin bedded limestone with shaly interbeds. Very fossiliferous; brachiopods, fenestrate bryozoans.		

		Stratigraphic Thickness Bed (Feet)	Total
(Con't.) 4.	Weathers into rubble....................	8.5	32.9
3.	Coral reef.		
	Crinoid-brachiopod fossil hash, fine grained, Cyathophyllum? sparse....................1.2 Dominantly Cyanthophyllum?, up to 6" long Transitional contacts....................1.5 Dominantly Favositids, flat and branching, mud matrix..............................2.0 Dominantly dome-shape favositids and Cyathophyllum? Many overturned. A few crinoid stems...........................2.5	7.2	24.4
2.	Limestone, exceptionally coarse-grained crinoid biosparudite. Parallel laminations and some very low angle cross-lamination. Some favositids; crinoid stems up to 1/4"...................................	10.0	17.2
1.	Limestone, less coarsely crystalline and more micrite than bed 2. Thinner and less massively bedded than bed. 2. Fine to medium grained brachiopod, bryozoan, crinoid fossil hash......................	7.2	7.2
	Covered at core of anticline		

Structurally the quarry at New Creek is the core of an unnamed small anticlinal flexure off the northwest flank of Wills Mountain anticline. Southwest along strike it is analogous to the Walker Ridge and Hopeville anticlines (to be studied later in the field trip). Northeast along strike, it and the Fort Hill anticline were possibly the same structure at one time. The Queens Point thrust has since complicated the strike and structural continuity of this structure.

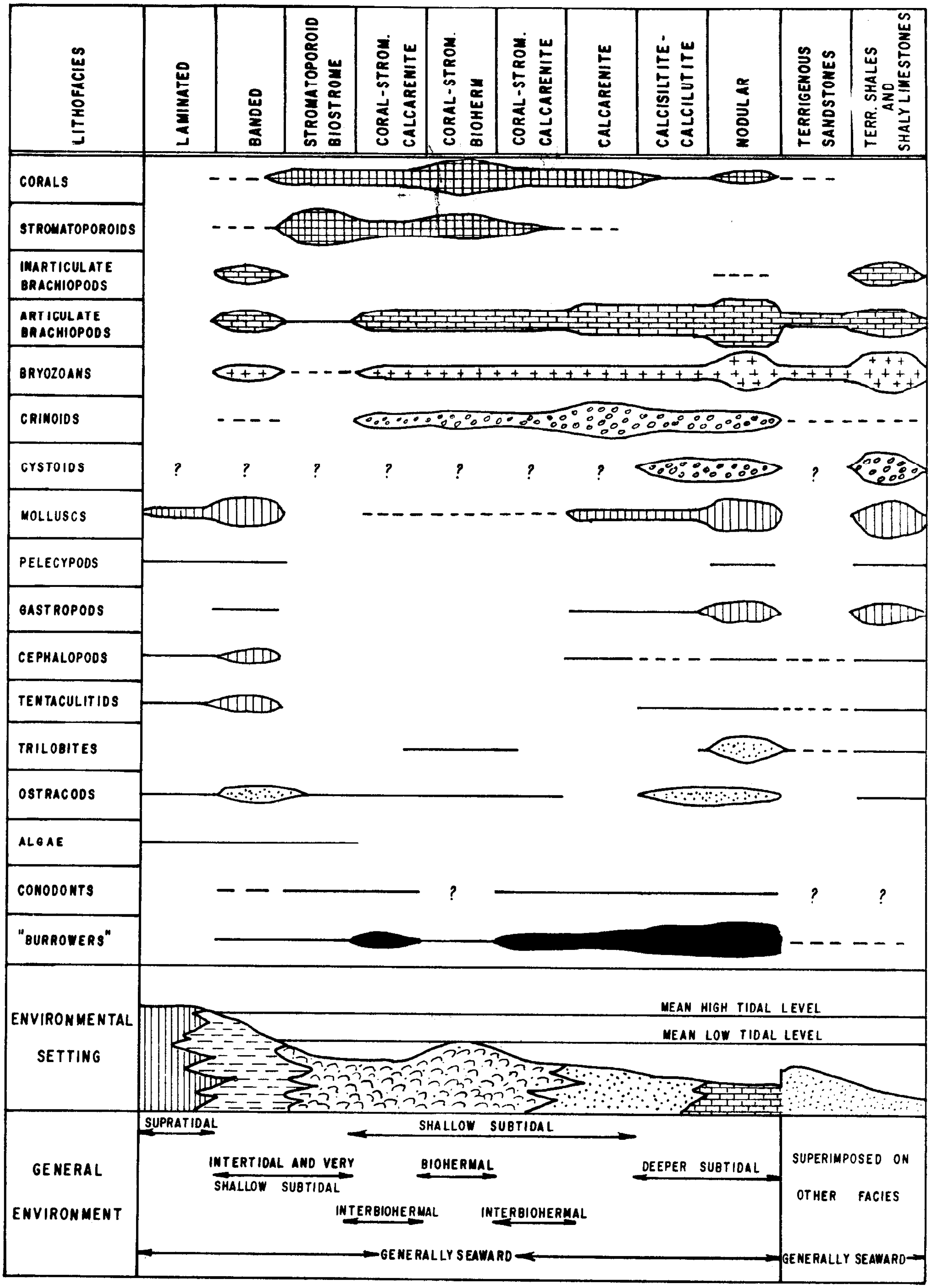
The southeast flank of this New Creek structure has been severely folded and broken by thrust faults several times (Figure 9). These same southeastward dipping thrust faults will be observed at the same stratigraphic position as we travel to the southwest.



NEW CREEK QUARRY (Head, 1969)

DRABISH AND SITES, 1981 (MODIFIED)

FIGURE 7

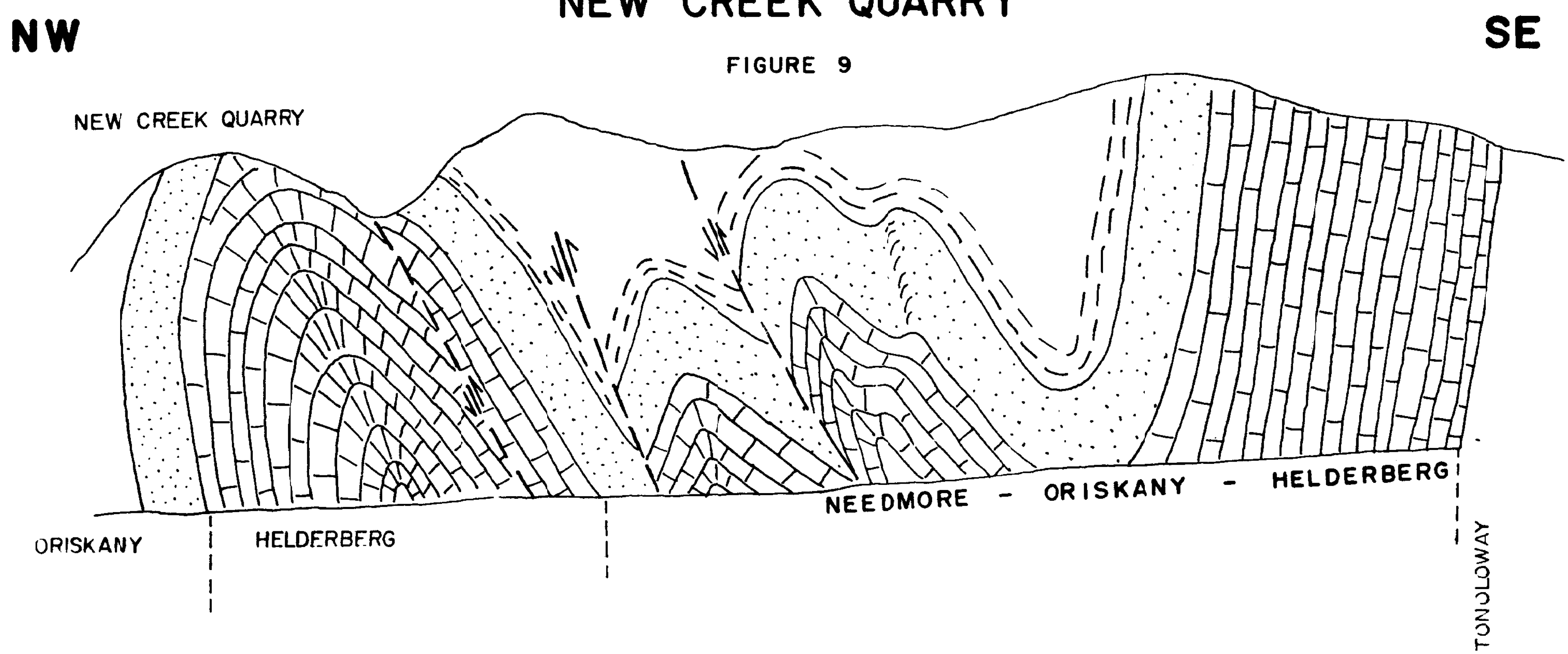


KEYSER LITHOFACIES, BIOFACIES, AND ENVIRONMENTAL RELATIONSHIPS. LITHOFACIES DESCRIPTIONS AND INTERPRETATIONS ARE PRESENTED IN "HEAD", 1969a.

FIGURE 8

GEOLOGIC PROFILE
ALONG
U.S. ROUTE 50
SOUTHEAST OF
NEW CREEK QUARRY

FIGURE 9



DRABISH AND SITES, 1981

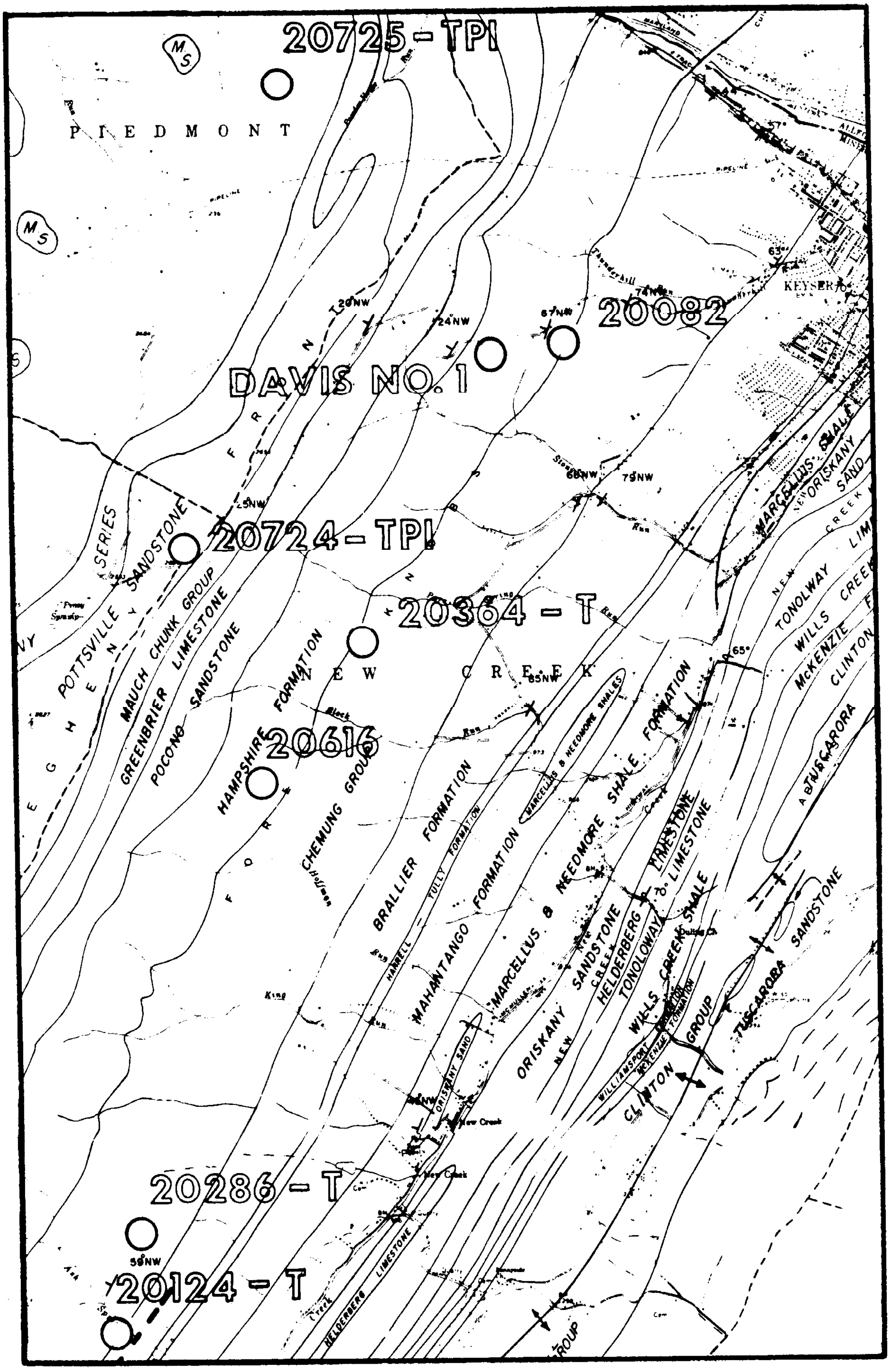
STOP 4. MASTELLAR COAL CO. NO. 1
Columbia Gas-20364-T
MIN.-16

This stop will afford everyone the opportunity to observe Wills Mountain anticlinorium, the Allegheny Frontal Zone, and the Structural Front in a panoramic setting. From here a discussion about the overall structural development of the anticlinorium, and its various structures will take place.

The northeast Queens Point and the Fort Hill anticline can be studied and put in perspective with Wills Mountain anticline, and its flanking structure. Note the Oriskany outcrop as it flanks Wills Mountain anticline on the northwest. These Oriskany exposures steeply dip to the northwest, attaining dips which vary from 45 degrees to overturned. The surface structure and topography as viewed from this vantage point are very impressive, as is the wavelength and amplitude of the Wills Mountain anticline.

Discussion at this stop will consider the surface geology, and interpretation of the subsurface structure as it relates to the Keyser Gas Field (Figure 10).

The chart on one of the following pages is a cross-reference list. It will aid in the identification of the various wells shown on the included geologic maps.



Geologic Map Of The Keyser Gas Field
1" = 4000'
(Modified from Reger, 1923)
Figure 10

CHRONOLOGICAL WELL NUMBER CROSS REFERENCE LIST

Mineral and Grant Counties, WV

Columbia Gas Well Number	Well Farm Name	State Permit Number	Location District-County	Year Drilled	Well Statue
F-36893	Greenland Lodge No. 1	Grt.-2	Union-Grant	1965	P & A
F-37836	P. B. Davis No. 1	Min.-2	New Creek-Mineral	1967	SG, P & A
20286-T	Wilbur Cather No. 1	Min.-11	New Creek-Mineral	1975	Did Not Reach Oriskany P & A
20364-T	Mastellar Coal Co. No. 1	Min.-16	New Creek-Mineral	1978	9,728 MCF/AF On Line
20619-T	Amtower No. 1	Grt.-3	Union-Grant	1979	P & A
20616	Mastellar Coal Co. No. 2	Min.-22	New Creek-Mineral	1979	88,148 MCF/AF On Line
20082	Richard Broadwater No. 1	Min.-26	New Creek-Mineral	1979	P & A
20124-T	Lucy Pancake No. 1	Min.-37	New Creek-Mineral	1980	Shut in/Testing
20179-TPI	Fairfax Sand and Crushed Stone Co.	Grt.-4	Union-Grant	1980	P & A
20725-TPI	Western Maryland Co. No. 1	Min.-59	Piedmont-Mineral	1981	SG, P & A
20724-TPI	Corcoran Gallery of Art No. 1	Min.-62	Elk-Mineral	1981	P & A

STOP 5. LUCY PANCAKE NO. 1
Columbia Gas - 20124-T
Min.-37

The subsurface structural deformation at this stop is mind-boggling. In the subsurface at this well location the Oriskany Sandstone was completely penetrated five times by the drillbit and yet less than one mile from this location, the Oriskany Sandstone is exposed.

Again, the overall structural framework of this area, surface and subsurface, will be discussed at this stop (refer to Figure 10).

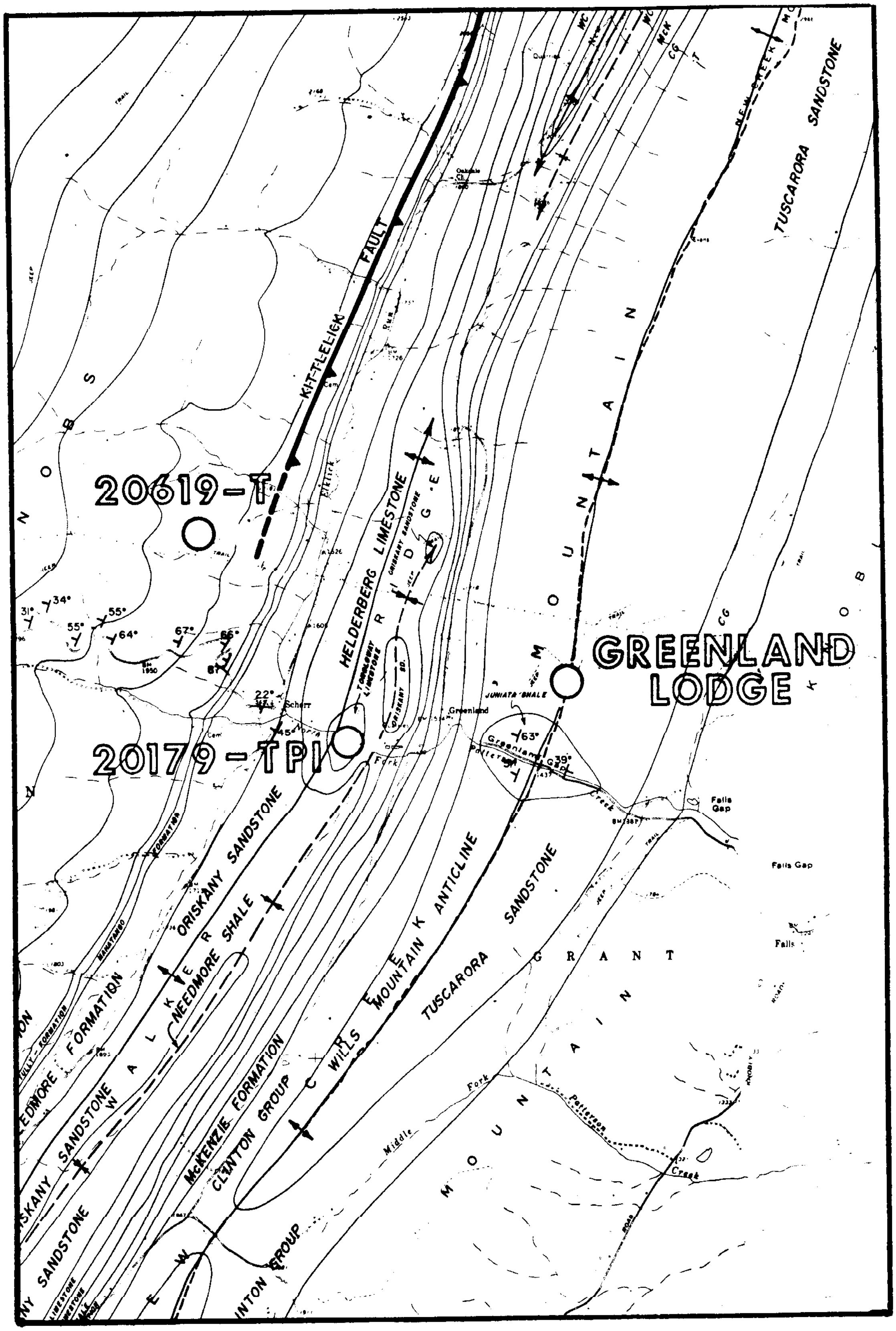
STOP 6. GREENLAND GAP
(Scherr Section)

This stop is located within the core of Walker Ridge anticline (Figure 11), analogeous to an earlier observed anticlinal structure at Stop 3, the New Creek quarry.

At road level a tight anticlinal fold of Upper Tonoloway Limestone can be observed. This tightly compressed structure appears to be faulted along its northwest flank (Figure 12). Note the longitudinal jointing and cleavage in its core. As a result, a topographic depression has developed due to differential weathering and erosion. Proceeding eastward along the road the Big Mountain Shale is exposed within the road bank to your left. This is the top of the Silurian, base of the Lower Devonian Helderberg Group. Within the Helderberg several southeast-dipping thrust faults are exposed. The Shriver Chert is also exposed as a large weathered zone, which has undergone deformation due to fracturing, faulting, and folding. Immediately southeast of this chert exposure is the axis of a very tight syncline which is associated with the Wills Mountain anticline to the southeast and the Walker Ridge anticline to the northwest.

The Tonoloway Limestone is being quarried along the southeast limb of this syncline. Discussion here at the quarry will focus on the subsurface structure throughout the Greenland Gap - Allegheny Frontal Zone area.

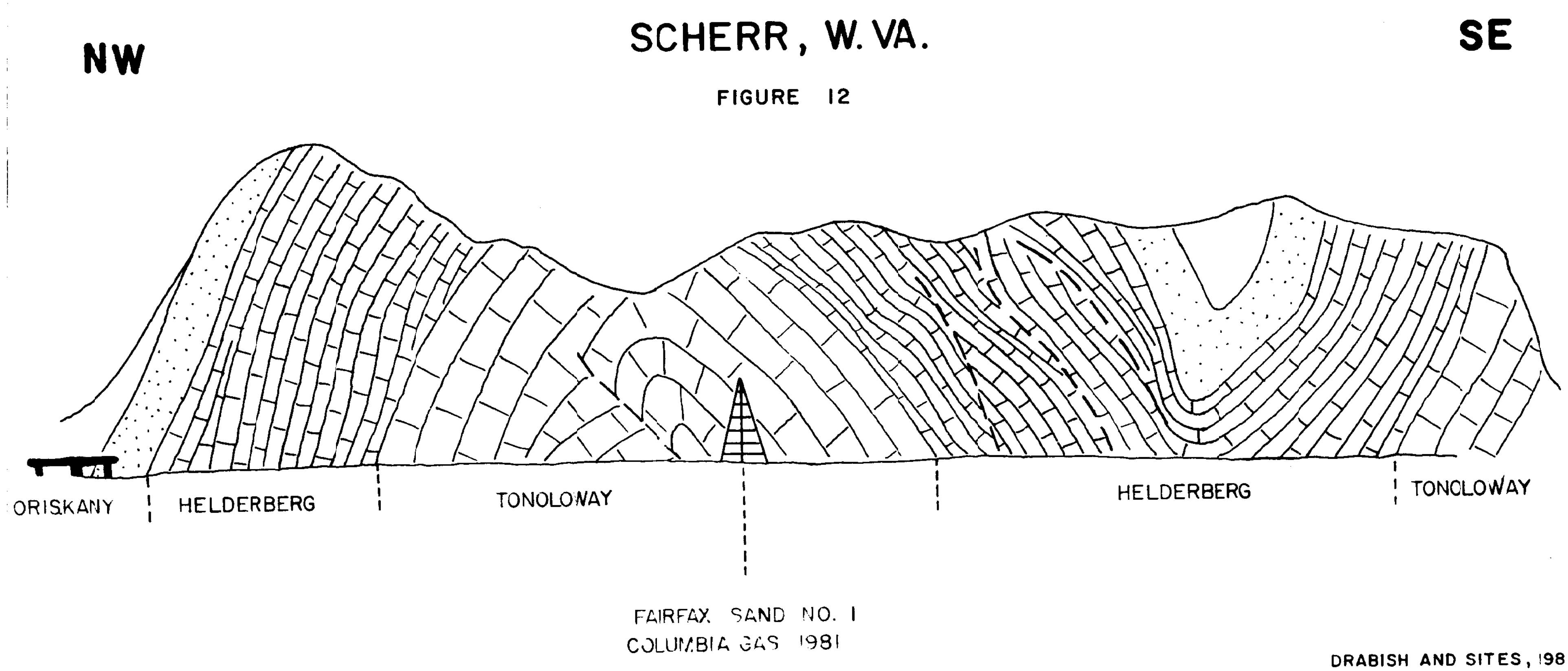
Well control, coupled with seismic through Greenland Gap, has greatly enhanced the subsurface structural interpretation for this part of Wills Mountain anticlinorium.



Geologic Map Scherr-Greenland Gap Area
1" = 4000'
(Modified from Reger, 1923)
Figure 11

GEOLOGIC PROFILE ALONG GREENLAND GAP ROAD AT SCHERR, W. VA.

FIGURE 12



STOP 7. GREENLAND GAP (Talus Slope)

Greenland Gap is the northernmost of four major water-gaps through the Wills Mountain anticline. The Silurian rocks exposed within the actual gap beautifully reflect the wavelength and amplitude of the surface on Wills Mountain anticline, the largest westernmost structure of the Valley and Ridge province. Here the fold exposes the Silurian Tuscarora Sandstone, shows northwestward asymmetry, and exhibits an unbreached crest along strike, unlike the crest further southwest, as will be seen later.

However the Tuscarora Sandstone does show some local deformation near the crest; there is a fold asymmetric to the southeast, which is probably a result of backthrust (southeastward directed) movement within the underlying Ordovician Juniata Formation. Also, with the use of binoculars, intraformational shortening in the form of wedging can be observed along the southeast flank of the major fold. This wedging phenomenon can be observed along strike of the entire structure, and represents a form of layer-parallel bedding shortening. The wedging effectively thickens the formation and juxtaposes any zones of primary porosity, as it appears to be an early, prefolding, stage of deformation. Many examples of this feature will be seen throughout the trip.

The gap does not appear to be fault controlled (Clark, 1967). The asymmetry of the gap profile is due to the southernmost side remaining in the sun-shadow allowing for more physical weathering along the northern slope. The large talus "boulder field" on the northern slope is most impressive. We will observe the core of the fold from the "Greenland Gap Boulder Field".

The Tuscarora Sandstone here has been measured along the southeast flank to be as much as 317 feet thick (Reger and Tucker, 1924). It is a massive, siliciously cemented, white quartzitic sandstone, as it is nearly everywhere.

STOP 8. GREENLAND GAP FALLS

This stop will enable you to observe the Lower Devonian Oriskany Sandstone and the underlying Shriver Chert member of the Helderberg Group. The North Fork of Patterson Creek has formed a picturesque waterfalls along the southeast dip-slope of the Oriskany Sandstone. The Oriskany Sandstone here is a massive, yellowish-brown, very fossiliferous sandstone, some 75 to 90 feet thick. Further southwest along strike, zones of calcareously-cemented quartz grains occur. The Helderberg Group here has been measured to be 976 feet thick (Reger and Tucker, 1924). The Shriver Chert directly underlies the Oriskany, and is a limestone with interbedded dark chert beds, also very fossiliferous, and was measured to be about 130 feet thick. In the past it has been erroneously referred to as the New Scotland Chert.

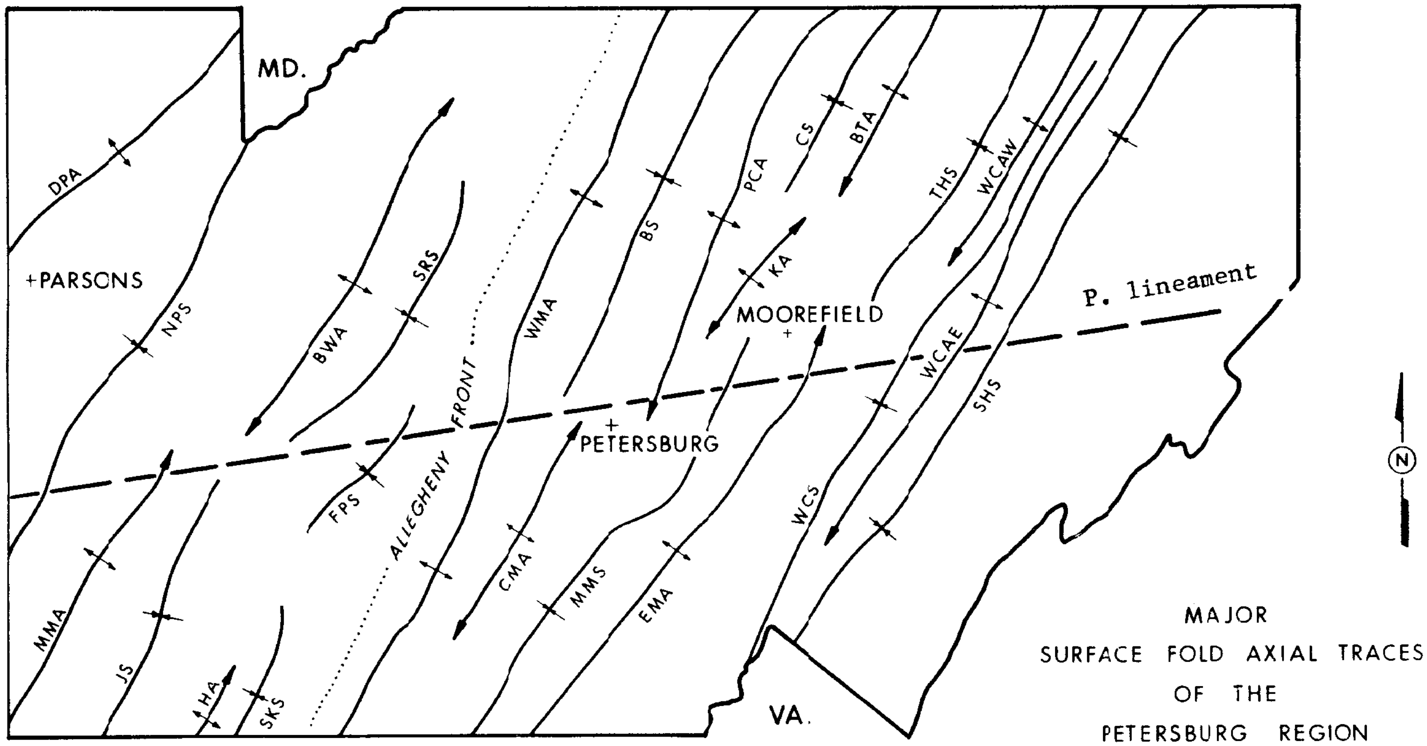
STOP 9. FORT HILL

At this location, an overall view of the regional geologic structures can be seen. An overview of the surrounding structures will be presented with emphasis on regional tectonics. Also, a regional correlation will be made to producing fields to the north-northeast.

This locality lies directly upon a major Central Appalachian cross-strike structural zone known as the Petersburg Lineament (Sites, 1978). The lineament is a zone of disrupted bedding orientations 3-½ to 5 miles wide trending N 70 - 80° E. for at least 95 miles (Figure 13). Disrupted fold axial-traces across the Plateau Province infer an additional 130 miles extension of the lineament to the west-southwest. In and near this Petersburg region, nearly all local large folds either bend or terminate along the lineament, with anticlines plunging opposite one another and into synclines (Figure 14). The lineament is recognizable in most photographic, structural, and geomorphic features observed.

Also from this vantage point, relative sizes of structures can be observed. Particularly, the amplitude and wave length of the Wills Mountain anticline can be related to the entire Wills Mountain anticlinorium at this locale.

Historically, Fort Hill holds the remains of hand-dug trenches and "bullworks" constructed by Union "homeguard" forces during the Civil War.



MAJOR
SURFACE FOLD AXIAL TRACES
OF THE
PETERSBURG REGION

SCALE
0 4 8 12 16
MILES

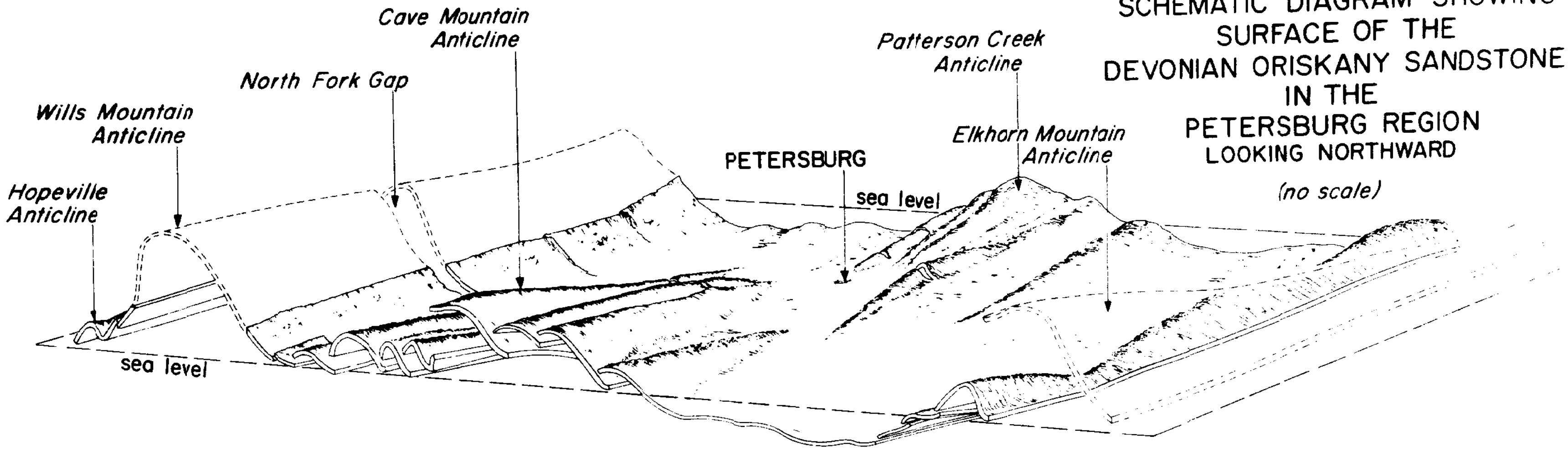
PLUNGING ANTICLINE

SYNCLINE

BS	Bedford Syncline
BTA	Broadtop Anticline
BWA	Blackwater Anticline
CMA	Cave Mountain Anticline
CS	Clearville Syncline
DPA	Deer Park Anticline
EMA	Elkhorn Mountain Anticline
FPS	Flatrock Plains Syncline
HA	Horton Anticline
JS	Job Syncline
KA	Kessel Anticline
MMA	Middle Mountain Anticline
MMS	Middle Mountain Syncline
NPS	North Potomac Syncline
PCA	Patterson Creek Anticline
SHS	Sideling Hill Syncline
SKS	Spruce Knob Syncline
SRS	Stony River Syncline
THS	Town Hill Syncline
WCAE	Whip Cove Anticline, East
WCAW	Whip Cove Anticline, West
WCS	Whip Cove Syncline
WMA	Wills Mountain Anticline

FIGURE 13

SITES, 1978



SCHEMATIC DIAGRAM SHOWING
SURFACE OF THE
DEVONIAN ORISKANY SANDSTONE
IN THE
PETERSBURG REGION
LOOKING NORTHWARD

(no scale)

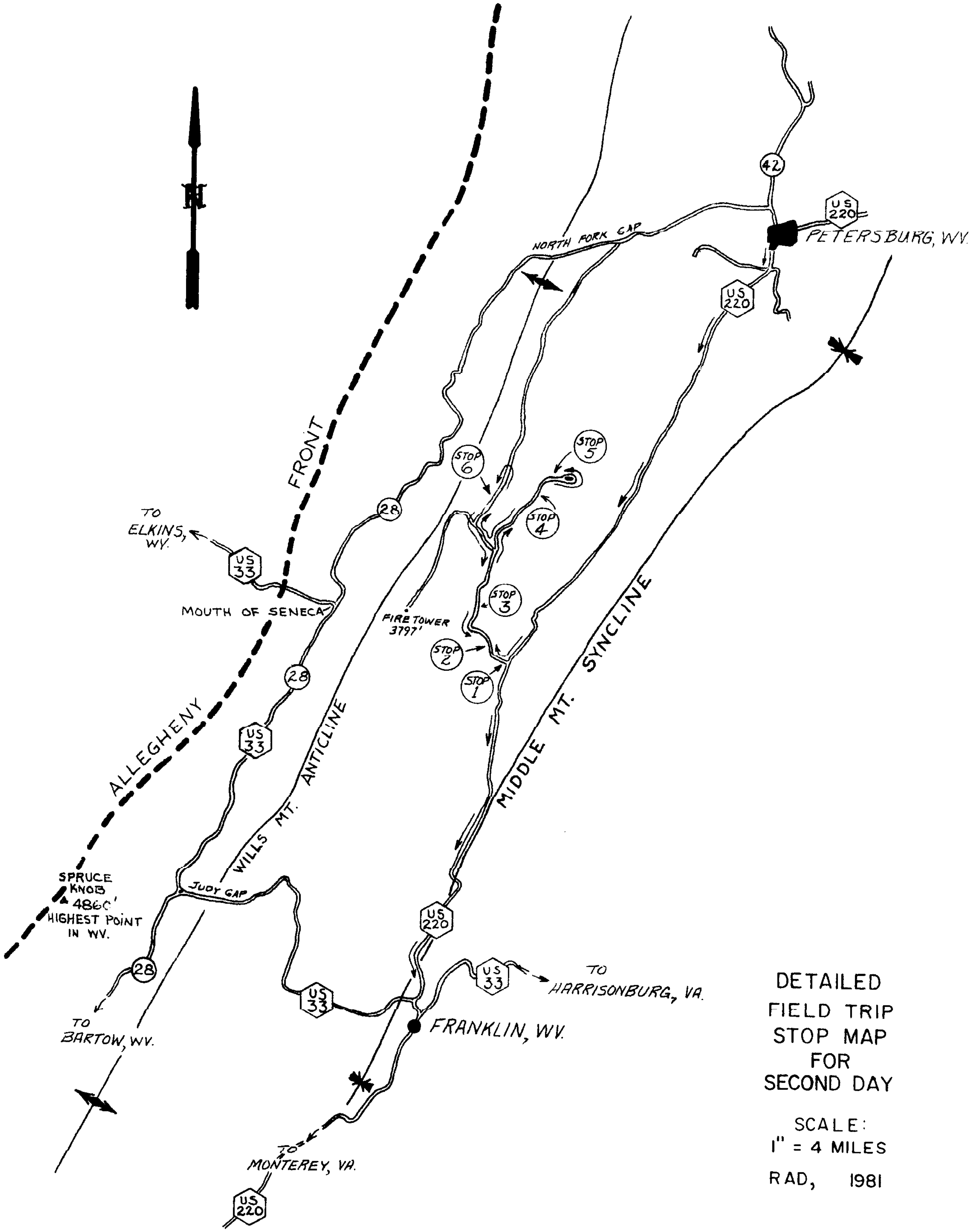
FIGURE 14

SITES, 1978

SECOND DAY

Men, I never took much stock in this God business. In fact I never believed there is a God at all. I have wanted to believe it, and tried to believe it, but never could. But since I have been here in the Smoke Hole and seen all this wonderful natural scenery, the wonderful formations of earth and stone, I'll be damned if I don't believe there is a God after all.

White, 1927



DETAILED FIELD TRIP STOP MAP FOR SECOND DAY

SCALE: 1" = 4 MILES

RAD, 1981

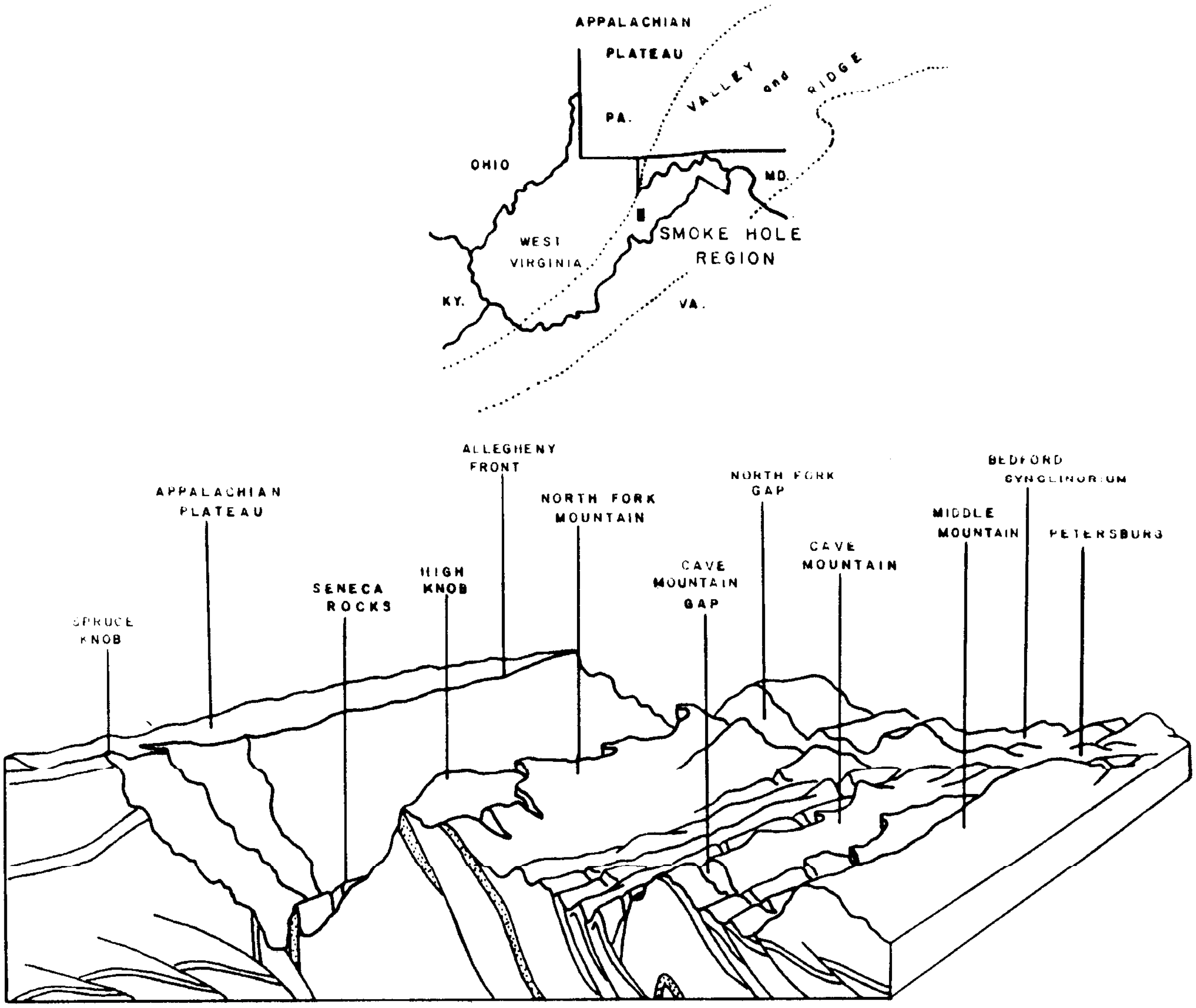
Introduction
to the
Smoke Holes

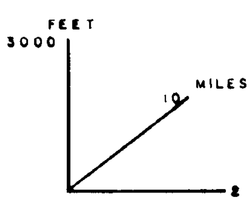
R. S. Sites
Exploration Geologist
Morris Exploration Co.

The Smoke Hole region geologically consists of the Cave Mountain anticline, an allocthonous structure thrust from the southeast. This unique area reveals the interior of this allocthonous structure, and presents us with an exposure of complex Central Appalachian structures involving the Silurian-Lower Devonian package of rocks. I and my few colleagues who have seen the area, believe that the Smoke Holes is without a doubt the most unique geologically exposed region within the Central Appalachians, and that they will serve (and have) as a surface model for complex subsurface structures shown or suspected by seismic and/or exploratory drilling (Figure 15).

This area is a somewhat isolated, inaccessible rugged mountainous-canyon region, now part of the Spruce Knob - Seneca Rocks National Recreational Area of the Monongahela National Forest. Cave Mountain represents the topographic and structural backbone of the Smoke Holes. The area is dissected by the pirated South Branch of the Potomac River, which flows northward through a narrow gorge for the entire length of the Smoke Holes. Unfortunately, we will be able to view only the southern half of this region (Figure 16).

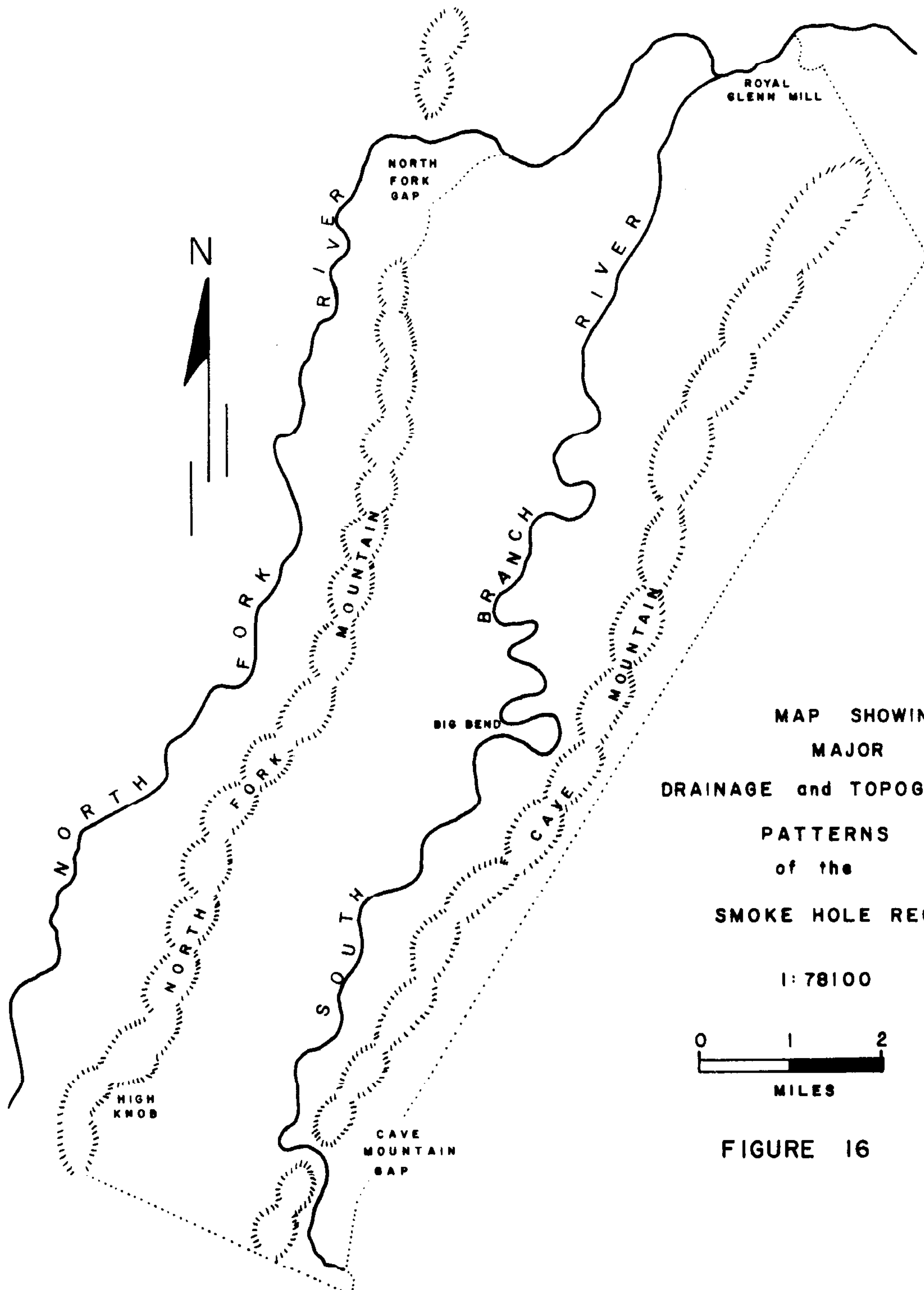
The stratigraphic column exposed in this region contains around 2400 feet of sandstones, limestones, and shales. This package of rocks is bounded on the lower and upper ends by two fairly competent sandstones, the Silurian Tuscarora and Devonian Oriskany, respectively (Figure 17). Therefore, this package behaves overall as a fairly





BLOCK RELIEF DIAGRAM
of the
SMOKE HOLES
and
SURROUNDING REGION
FIGURE 15

SITES, 1973

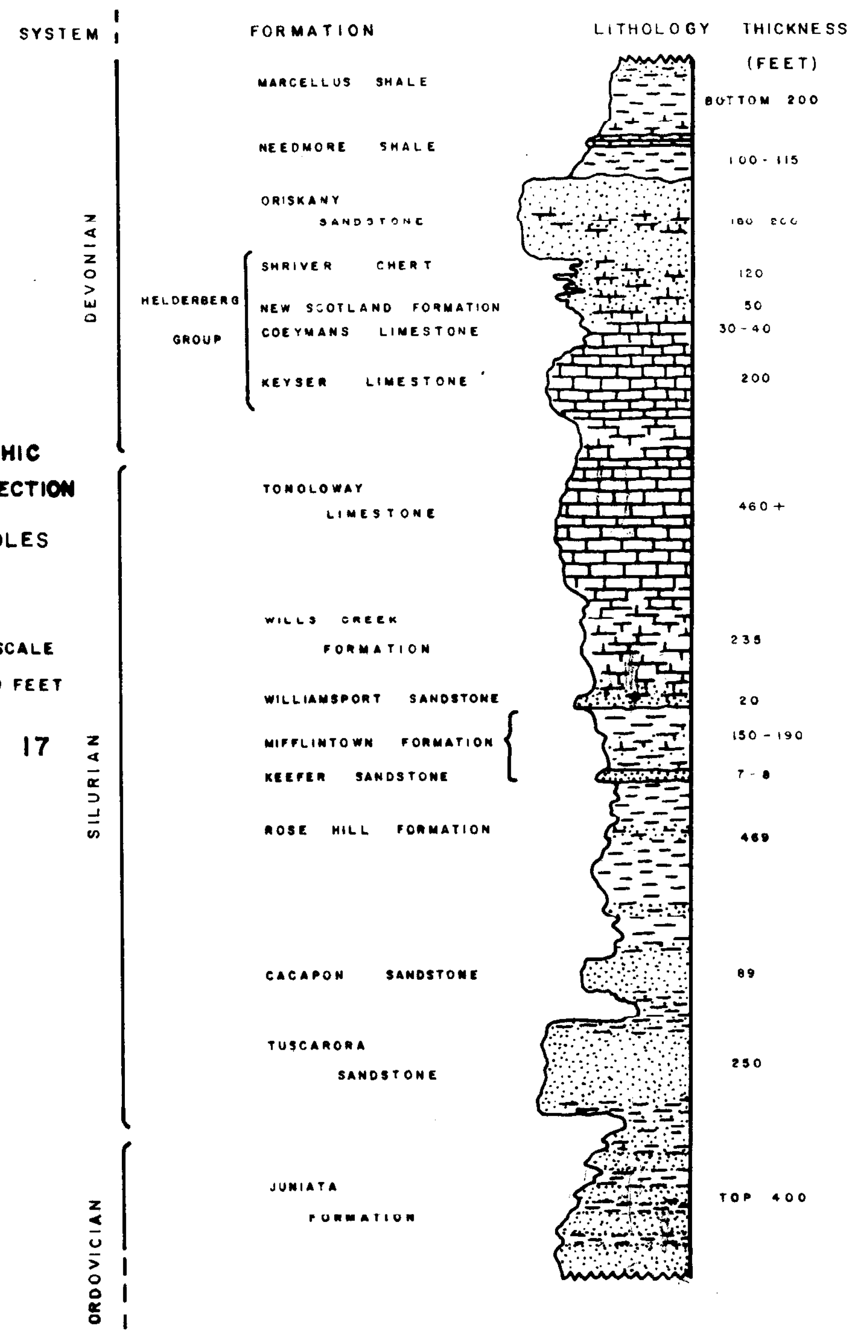


MAP SHOWING
MAJOR
DRAINAGE and TOPOGRAPHIC
PATTERNS
of the
SMOKE HOLE REGION

1: 78100

0 1 2
MILES

FIGURE 16



STRATIGRAPHIC COLUMNAR SECTION of the SMOKE HOLES

VERTICAL SCALE
1 INCH = 350 FEET

FIGURE 17

competent litho-tectonic unit, but as it is a relatively thin unit within the Paleozoic strata, it has buckled and broken with relative ease. Bear in mind that these rocks are sandwiched between thick overlying Devonian shale formations and a thick underlying Ordovician shale section.

The geology of the Smoke Holes is dominated by the Cave Mountain anticline. The anticline trends N 34° E, and is faulted along the southeast-dipping Cave Mountain thrust, against the southeast limb of the Wills Mountain anticline. The Cave Mountain anticline has an asymmetric to slightly overturned northwest limb, which exhibits a zone of southeast-dipping imbricate thrust faults. It is a doubly-plunging fold showing a culmination with closure at the Lower Silurian level in the center of the area, and dividing into several plunging folds upsection at the Lower Devonian level on each end of the fold (Figure 18).

The Cave Mountain anticline consists of subparallel, southeast-dipping, northeast-striking thrust faults with a maximum stratigraphic displacement of approximately 1900 feet, throwing Lower Silurian rocks against Lower Devonian rocks (Figure 19). The Cave Mountain anticline is structurally bounded to the northeast and southwest by major cross-strike structural lineaments; the Petersburg lineament and an extension of the Parsons lineament, respectively.

The Cave Mountain anticline shows a maximum structural relief of nearly 2800 feet at the Oriskany level. It is narrower at the southwest end, plunging 8 to 15 degrees southwestward, whereas, at the northeast end it divides into several folds that plunge 20 to 25 degrees northeastward into the Bedford Syncline. Fracture orientations

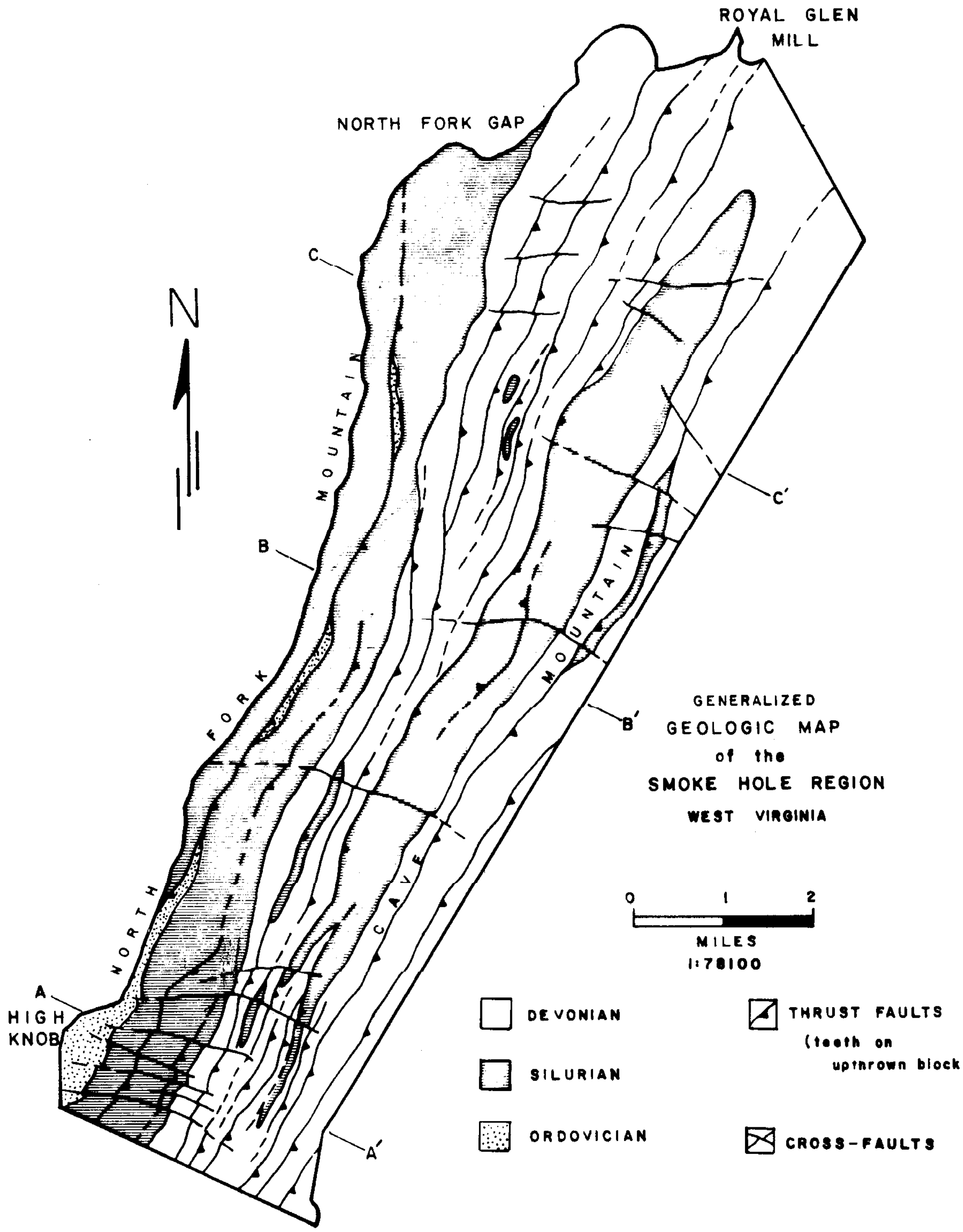
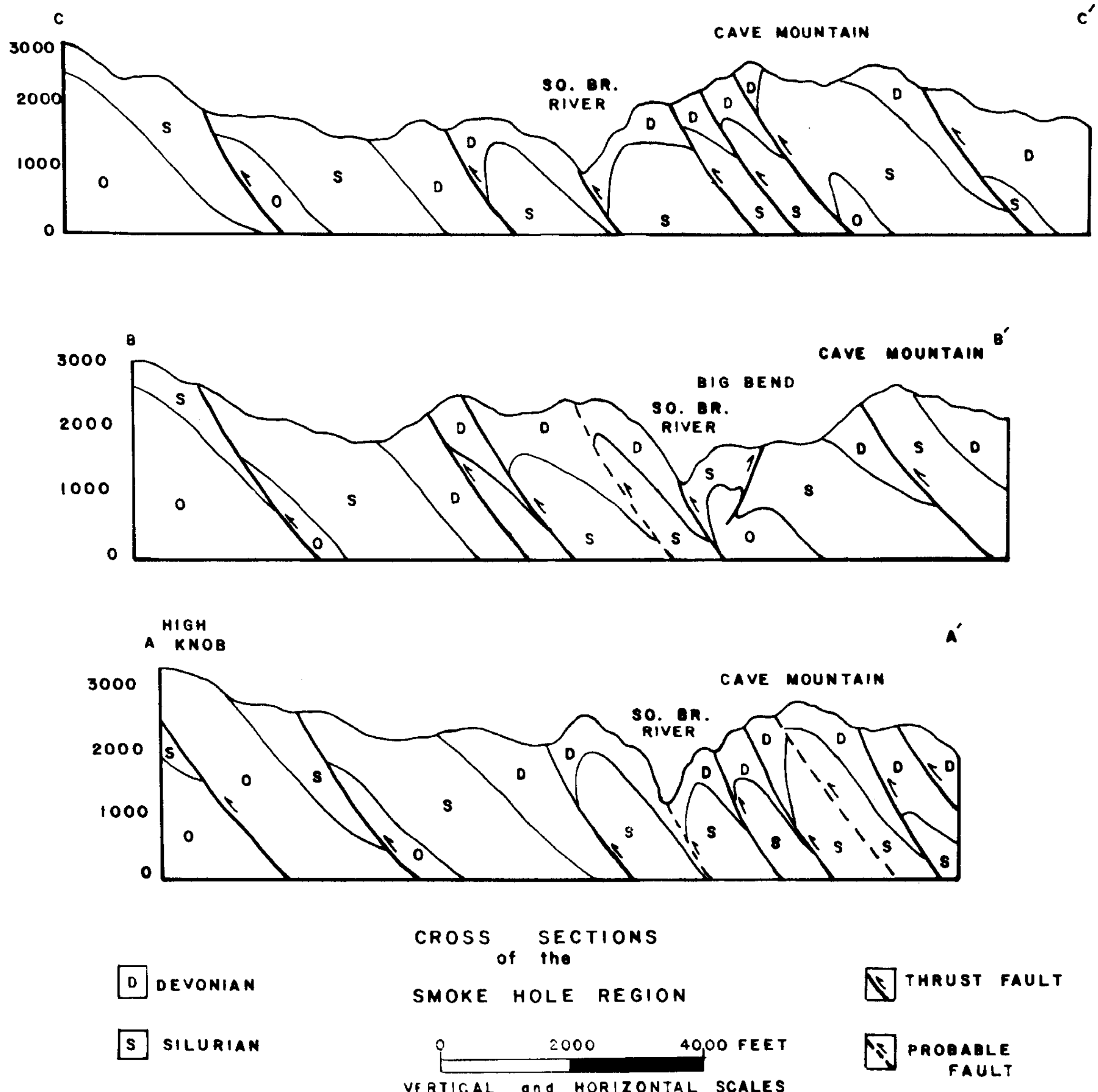


FIGURE 18

SITES, 1973



CROSS SECTIONS
of the
SMOKE HOLE REGION

FIGURE 19

SITES, 1973

throughout the Smoke Holes basically show a decrease in the number of longitudinal joints over the culmination with an increase towards the plunging anticlinal noses while consistant predominate sets of diagonal joints prevail throughout the area (Figure 20).

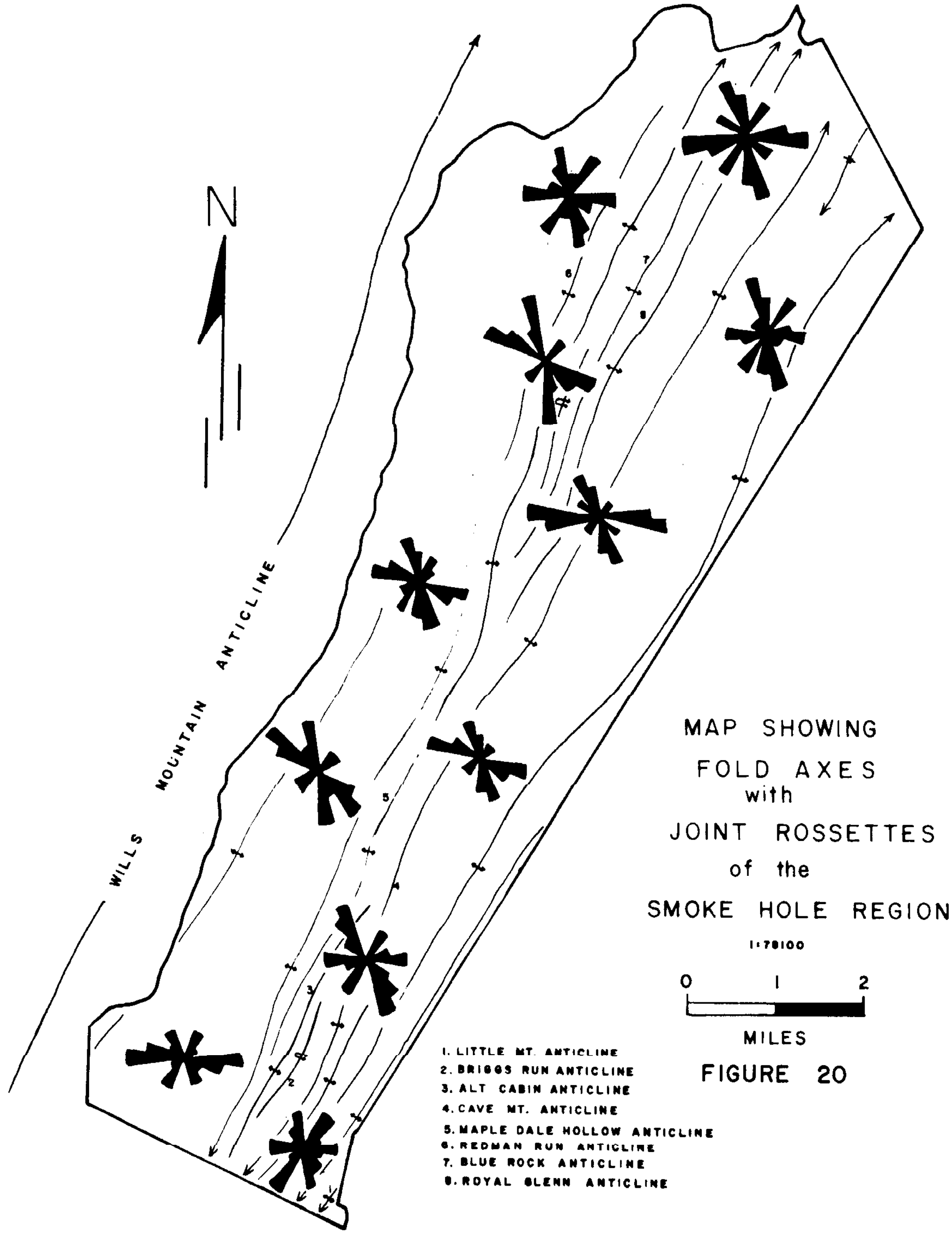


FIGURE 20

SITES, 1973

STOP 1. BIG MOUNTAIN ANTICLINE

This is the first of three thrusted anticlines we will traverse. They occur along the southeast limb of the Cave Mountain anticline. As will be observed all folds show the Oriskany Sandstone. They are asymmetric to the northwest. This particular stop exposes nearly the entire Oriskany Sandstone. The fold has a very gently dipping southeast limb leading into a very steeply dipping northwest limb. The core of the fold is thickened by intra-formational wedging. Evidence of longitudinal joint density is noted by a deeply weathered zone near the crest. Lower-most Devonian shale formations can be observed along the northwest limb, where they have been dragged into the leading frontal edges of the splay thrusts.

Throughout this region, the Oriskany can be divided into two distinct members. The lower member consists of a medium gray to light-gray, medium bedded, block-jointed, calcareously cemented quartz sandstone. The lower member is not as fossiliferous as the upper member. The upper member consists of gray to brown, medium to coarse grained, very fossiliferous sandstone. There is an occasional thin zone of calcareously cemented sand. Probably, the Oriskany here represents a reworked beach deposit, with alternating clean and dirty, well sorted and poorly sorted sands, to a shallow intertidal-subtidal shoal area.

STOP 2. CAVE MOUNTAIN GAP

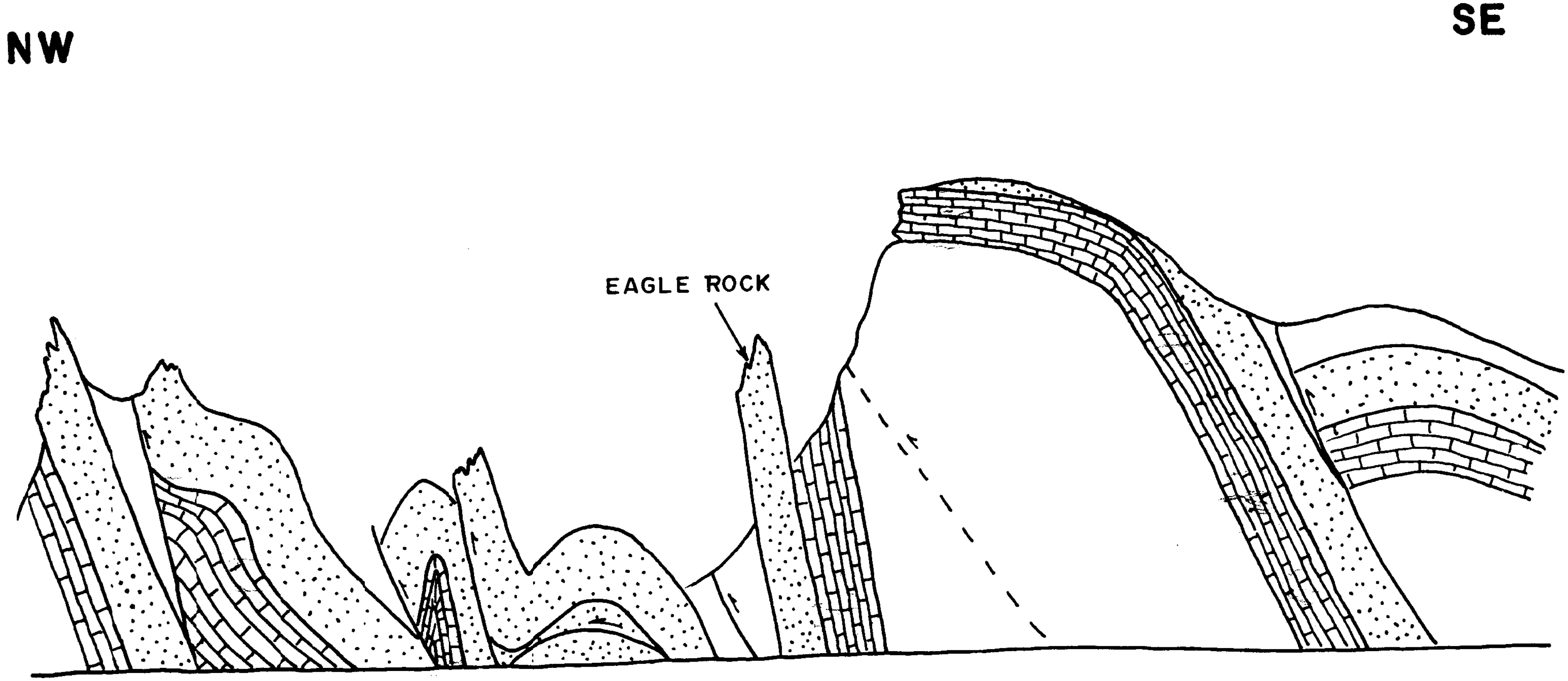
This will be a long traverse through the Cave Mountain anticline and along its northwest limb. We will start the traverse at an exposure of steeply-dipping Devonian Helderberg chert beds along the southeast limb of the fold and terminate at a very tight fold involving the Oriskany Sandstone. This traverse will allow one to view the amplitude and wavelength of the Cave Mountain anticline and also afford excellent views of the suballocthonous foot-wall block. As we start through the gap there is a magnificent view of this structure and its relationship to the southeast limb of the Wills Mountain anticline which we observed the previous day.

The Tonoloway Formation of Silurian age is exposed within the core of the Cave Mountain anticline. The northwest limb is beautifully exposed with a large overturned exposure of Oriskany Sandstone known as "Eagle Rock". The anticline is slightly breached, and is capped by large cliffs of Devonian Helderberg carbonates. Beyond "Eagle Rock", we will view very complex structures principally involving the Oriskany Sandstone. One will be able to observe the drag deformation between thrust faults, as well as, a good exposure of a thrust plane (Figure 21).

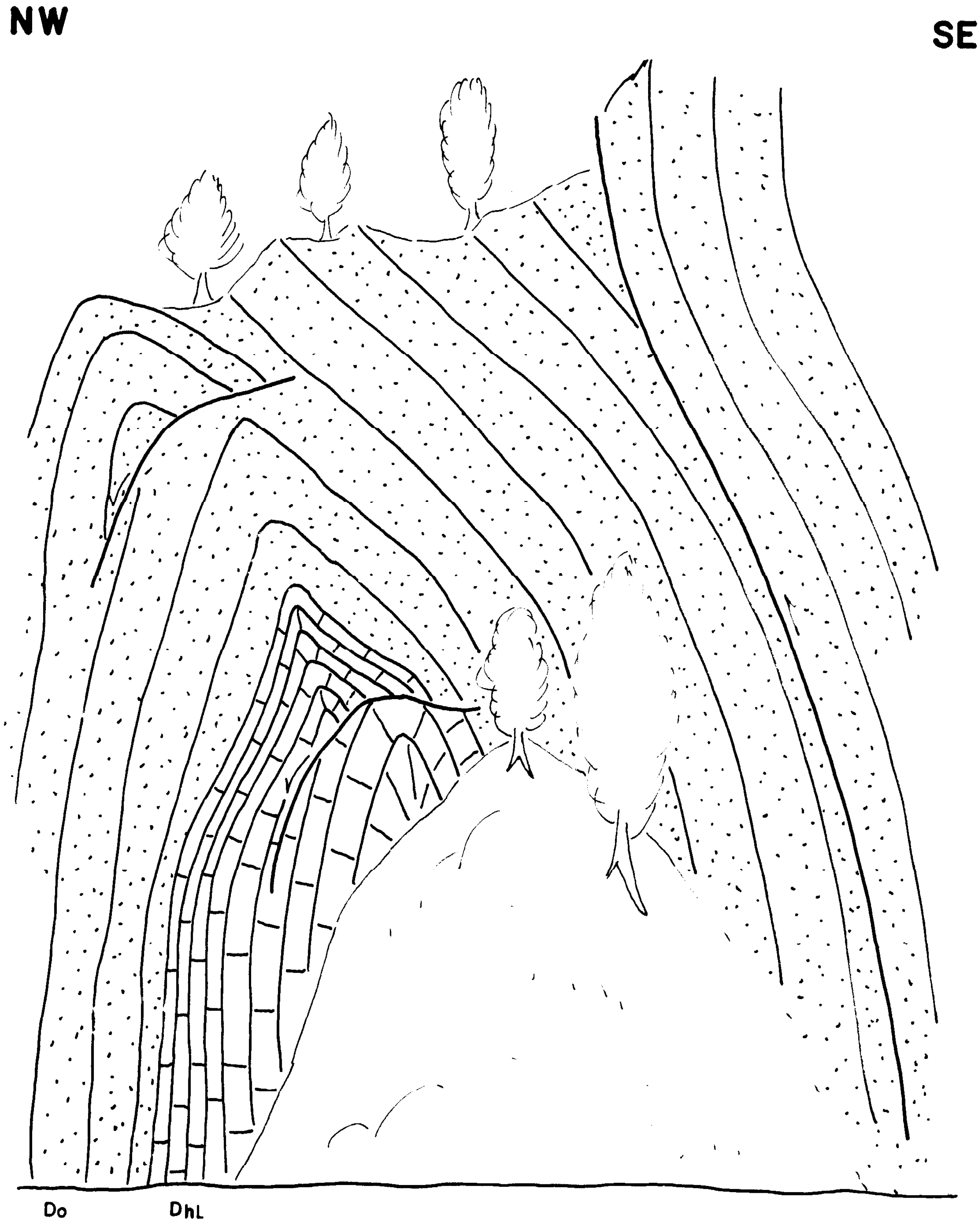
Our traverse will end at a fold involving Oriskany Sandstone. This is a vertical isoclinal fold. The core shows some displacement from continued movement along bedding planes. This structure is called the Alt Cabin anticline (Figure 22).

CAVE MOUNTAIN GAP

FIGURE 21



SITES, 1982



ALT CABIN ANTICLINE

FIGURE 22

SITES, 1982

STOP 3. SMOKE HOLE CAVE

This particular stop is made to allow observation of carbonates involved in thrusting offset by a cross-strike tear fault. Exposed are the Silurian Tonoloway through Devonian Oriskany Formations. The carbonates are so highly deformed that bedding plane recognition because of cleavage is difficult to recognize. This may also be partly due to the lack of well-defined bedding within the "patch reef" facies of the Silurian/Devonian Keyser Formation (Lower Helderberg).

The Smoke Hole Cave, located in large cliffs above the road, is developed in Devonian Helderberg limestones striking nearly north with a low westerly-dip. The strike of the narrow cave passage is subparallel to the tear fault strike; nearly east-west.

In all reality, as you will observe, this is one of those exposures where we really do not have all the answers. There is a great deal of deformation involved; bed identification and continuity along strike is very difficult to recognize. At the end of the traverse, there is repetition of the Upper Helderberg Corriganville Limestone which exhibits disharmony between two large exposures.

Here one can also observe interference patterns between disharmonic minor folds along the intersection of the thrust and tear fault zones.

This stop is truly a zone of "discombobulation".

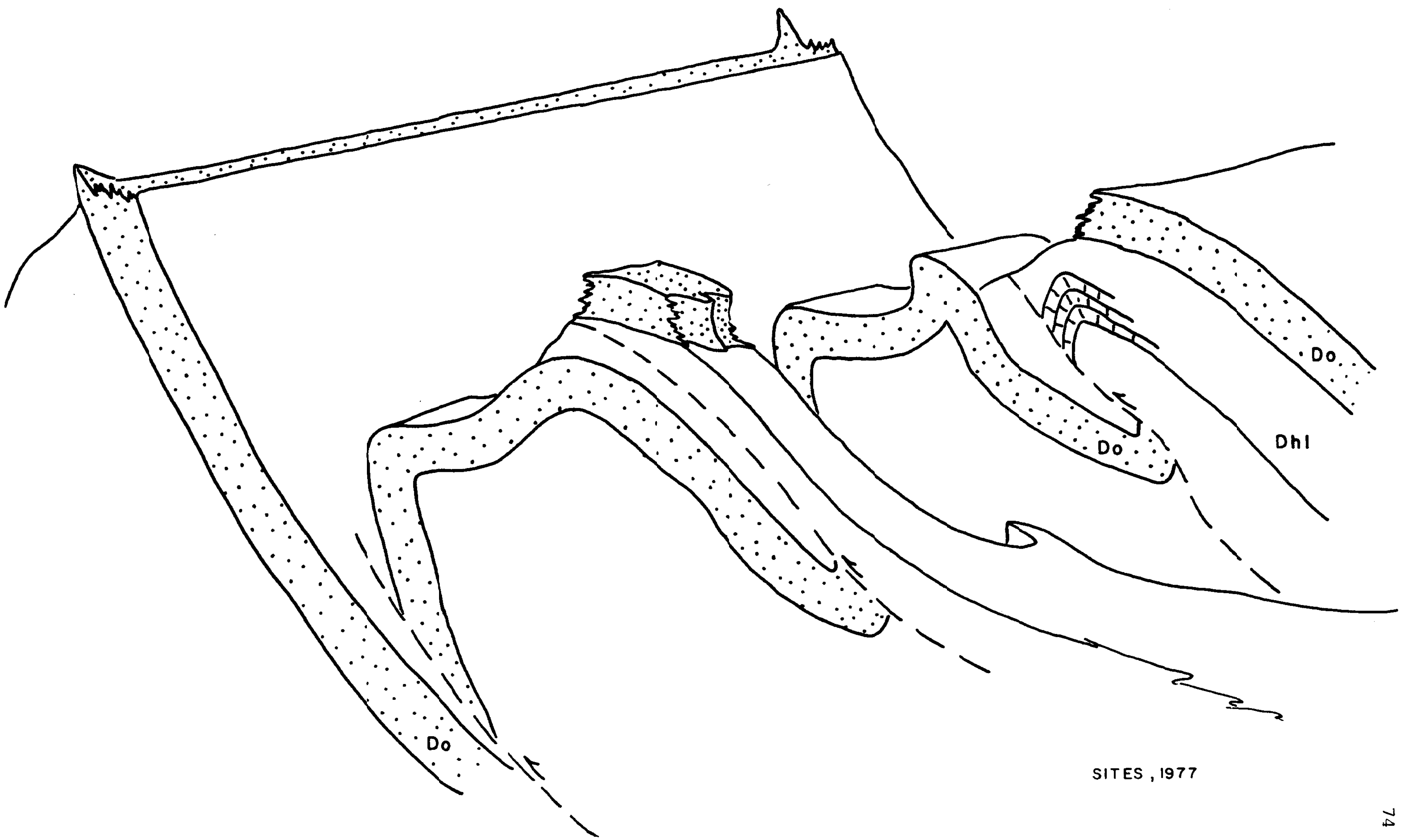
STOP 4. MAPLEDALE HOLLOW

Mapledale Hollow is a beautiful, narrow, water gap developed through a complex suballocthonous structure below the Cave Mountain thrust. Actually this exposure reveals the water gap to be located within a fenster developed through a thrust sheet with a remnant klippe of Oriskany Sandstone. Three separate layers of Oriskany Sandstone can be observed at this stop, each with a different bedding orientation (Figure 23). The principal anticline seen here has a vertical to overturned northwest limb, which has been dragged with movement along the very steeply-dipping footwall block. Within the crest of the principal anticline is very tight folding involving the Oriskany Sandstone. This minor folding plunges southward across the gap, exhibiting rapid change of structures along strike. Located above this principal anticline along the southside of the gap, is a klippe of an overriding sheet of Oriskany Sandstone. Along the north side, further along strike, can be seen the same overriding Oriskany Sandstone sheet, still beneath the Cave Mountain thrust. Also along the north wall of the gap can be seen drag of the Helderberg chert beds on the hanging wall of this thrust, above the Oriskany Sandstone. As you will no doubt note, differential weathering confuses the issue by presenting a false impression of two separate structures from one side of the gap to the other.

MAPLEDALE HOLLOW

(LOOKING NORTHWARD)

FIGURE 23



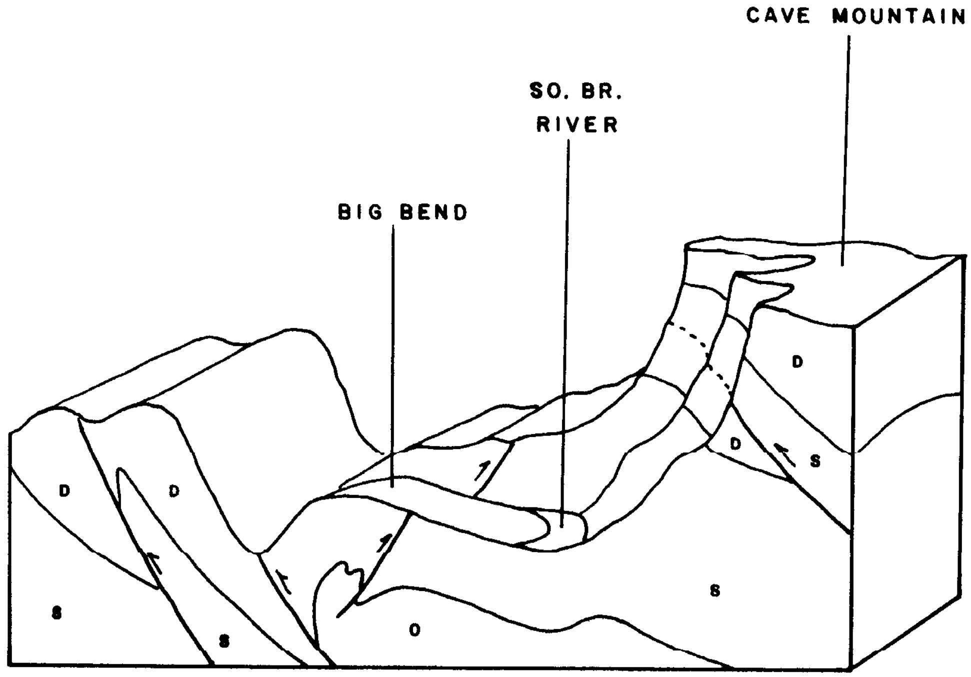
SITES, 1977

STOP 5. BIG BEND

Big Bend is the core of the Cave Mountain anticline along its maximum culmination. Here the anticline is breached exposing the top-most beds of the Silurian Tuscarora Sandstone, the oldest rocks exposed in the Smoke Holes (Figure 24). Big Bend will afford us an excellent chance to view the core of the Cave Mountain anticline. Along this traverse will be seen the stratigraphic displacement on the Cave Mountain thrust and the inner-core structure at the Lower Silurian level on the upthrown block. Within the core of the fold a local northwest-dipping reverse fault has developed, referred to as the "Big Bend Backthrust". This backthrust extends nearly two miles along a northeast strike and shows a maximum stratigraphic throw of approximately 100 feet with associated drag effects. It is conjugate with, but does not appear to intersect, the Cave Mountain thrust (Figure 25). Drag from the associated backthrust has further complicated a previously developed subsidiary anticline, asymmetric to the northeast with a southeastward dipping axial plane. This previously developed subsidiary anticline is now viewed as a refolded, rotated asymmetric fold (Figure 26).

Along the crest of the Cave Mountain anticline at the top of the Tuscarora Sandstone, there are two oppositely plunging anticlinal folds. These two structures serve to help concentrate zones of fracturing along the crest of this overall fold. As you will observe, this is not a simple "roll-over" of an anticline. Also note the style of deformation that a massive member such as the Tuscarora can undergo when subjected to compressional tectonism (Figure 25). Within the Tuscarora you will also note pre-Cave

Mountain anticline structures, analogous to those pre-Wills Mountain structures mentioned earlier and those you will see on the following day. This is truly one of those remarkable exposures that will enable us a circular traverse. We will be able to walk completely around and through this complex anticlinal arch of Silurian age rocks.



BLOCK DIAGRAM
of
BIG BEND
SMOKE HOLES, WEST VIRGINIA

FIGURE 24

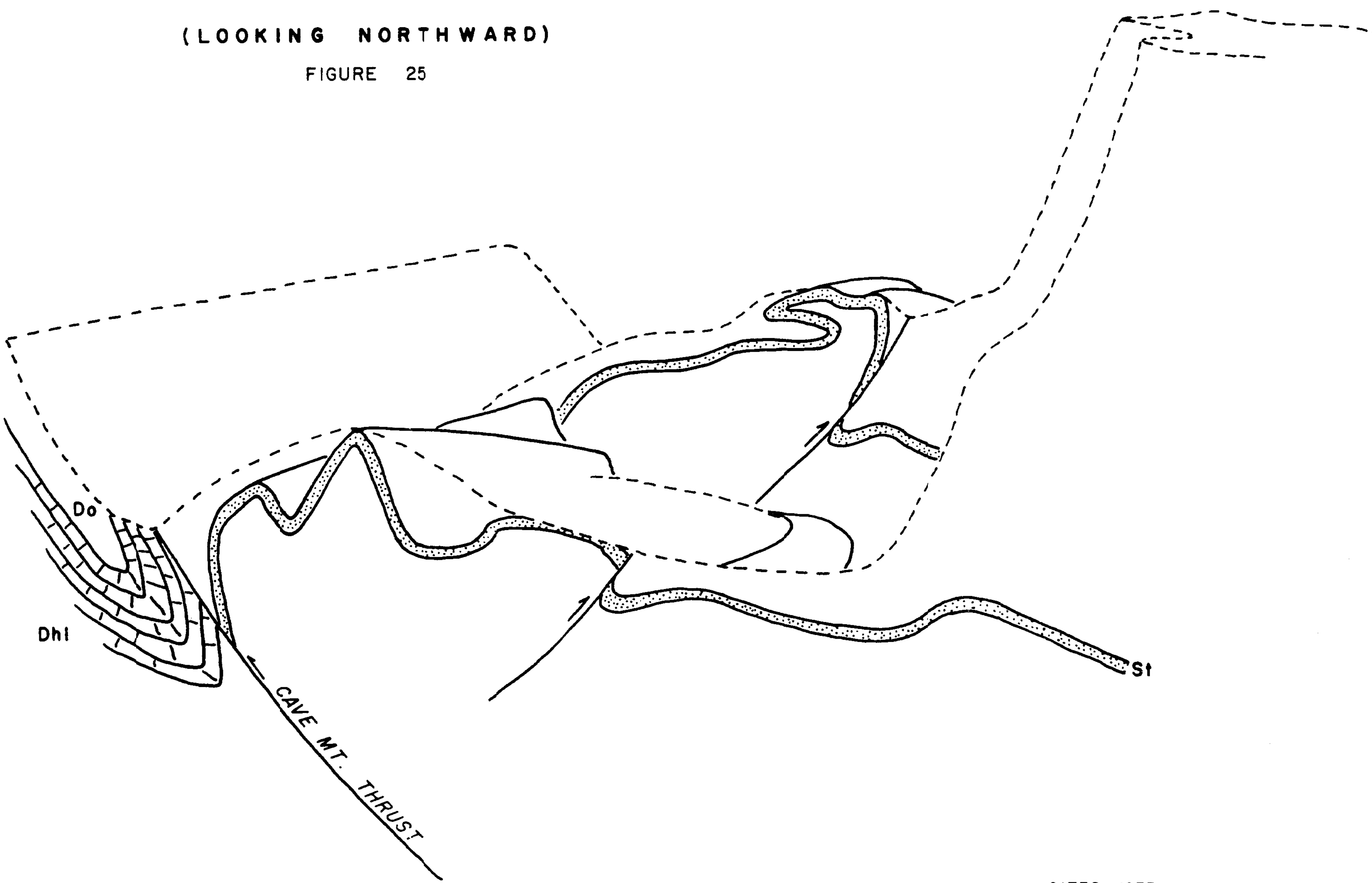
D DEVONIAN S SILURIAN O ORDOVICIAN

SITES, 1973

BIG BEND

(LOOKING NORTHWARD)

FIGURE 25

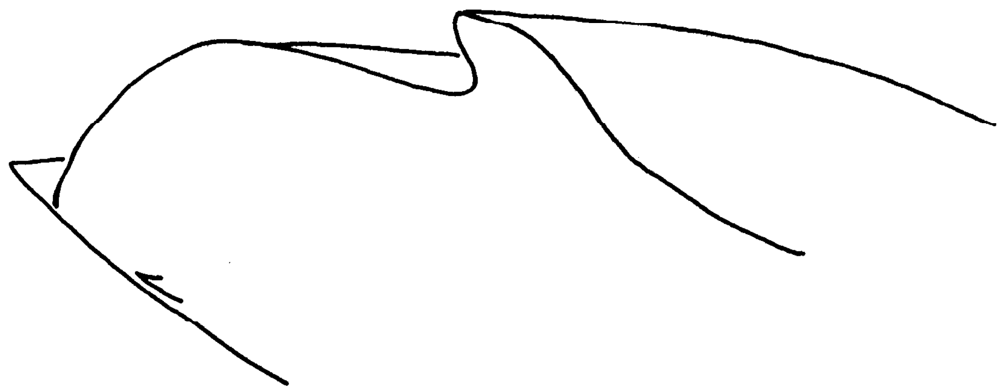


SITES, 1977

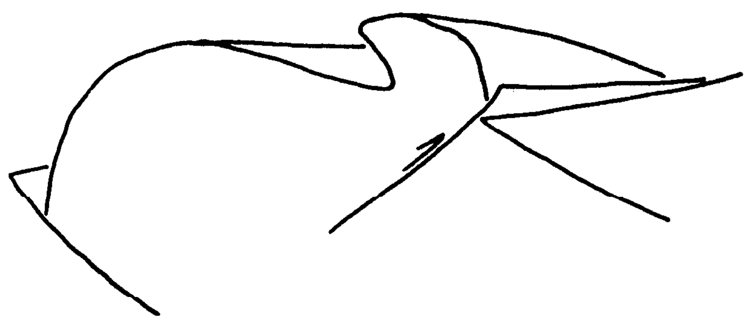
BIG BEND

(LOOKING NORTHWARD)

FIGURE 26



INITIAL MOVEMENT; CAVE MTN. THRUST (COMPRESSION).



NON-MOVEMENT ALONG CAVE MTN. THRUST; TENSIONAL RELEASE VIA ASSOCIATED BACKTHRUST.

CONTINUED COMPRESSION AND ANTICLINAL ROTATION.

SITES, 1977

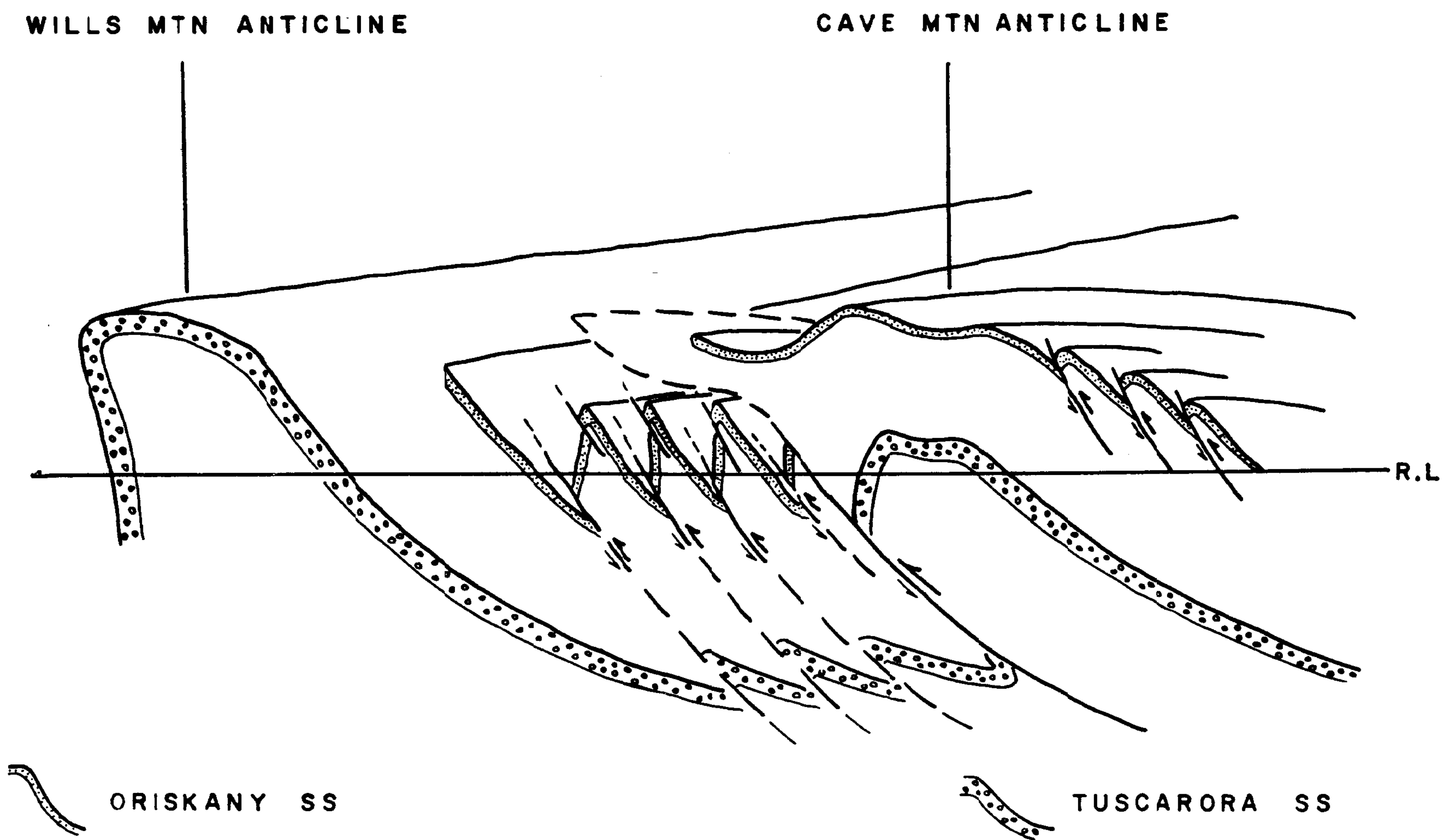
STOP 6. SMOKE HOLE OVERVIEW

The view from this overlook will enable one to observe several Smoke Hole structures as related to the Cave Mountain anticline. Here we will see four exposures of Oriskany Sandstone with a fifth implied from the crest of Cave Mountain. All these have been thrust one on top of another, and presents us with an overall view of a fairly large scale shear zone associated with the Cave Mountain thrust. It is possible that some of these folds were initially more symmetrical, and were later squeezed, and tightened up as the Cave Mountain thrust moved material over them. This created a massive, complex zone of tight folding and additional faulting within the footwall block of the Cave Mountain anticline. The result was literally a "piling" of Lower Silurian through Lower Devonian strata against the, probably already existing, Wills Mountain anticline (Figure 27).

SMOKE HOLE "SHEAR ZONE"

(LOOKING NORTHWARD)

FIGURE 27

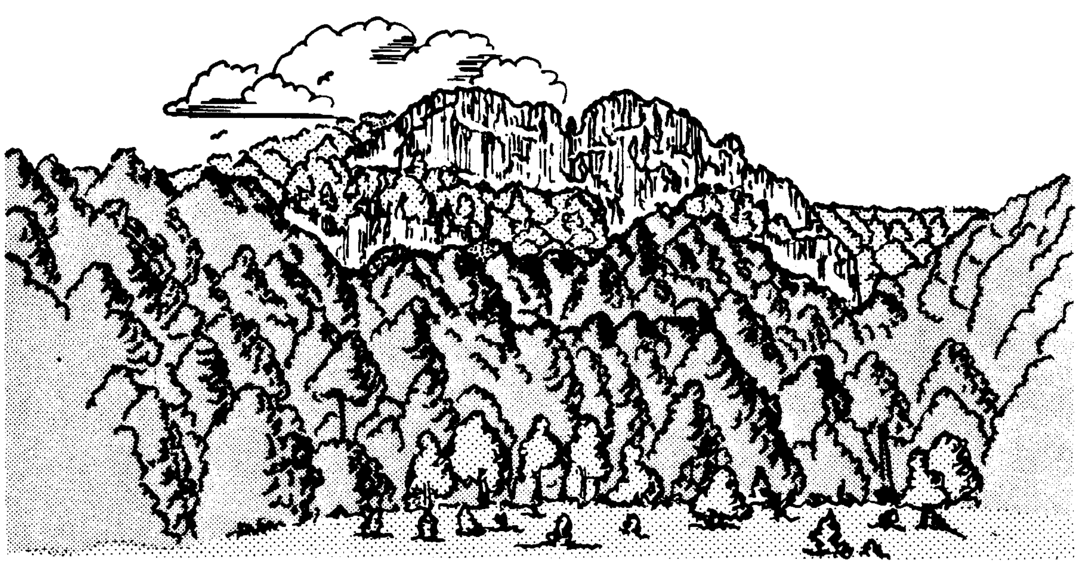


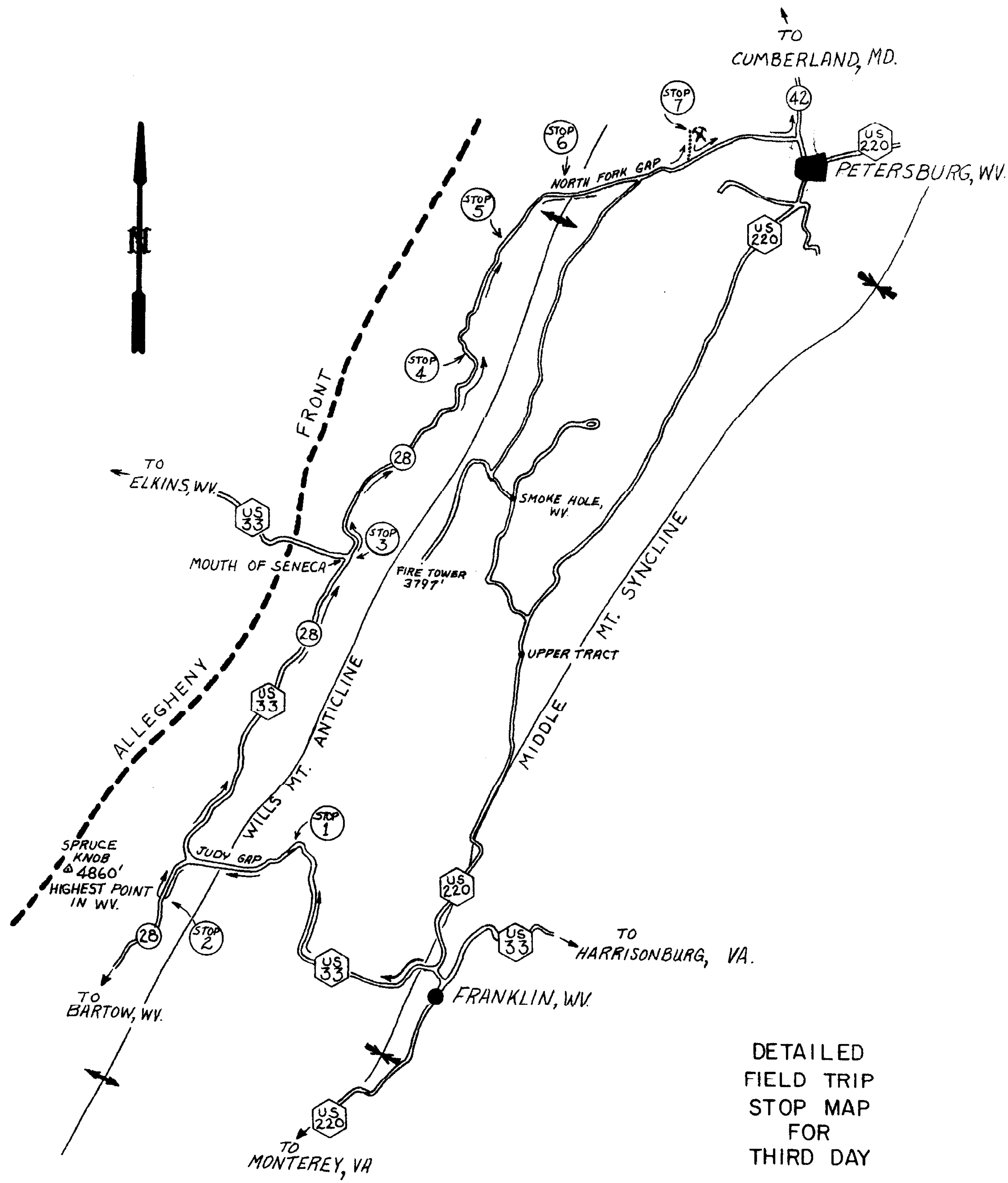
SITES, 1977

THIRD DAY

Geologist, rejoicing in the abrasions, upheavals and contorsions, the earthquake agonies of mother earth, up the North Fork you will find things ripped up to your satisfaction.

Porte Crayon, 1851





DETAILED
FIELD TRIP
STOP MAP
FOR
THIRD DAY

SCALE:
1" = 4 MILES

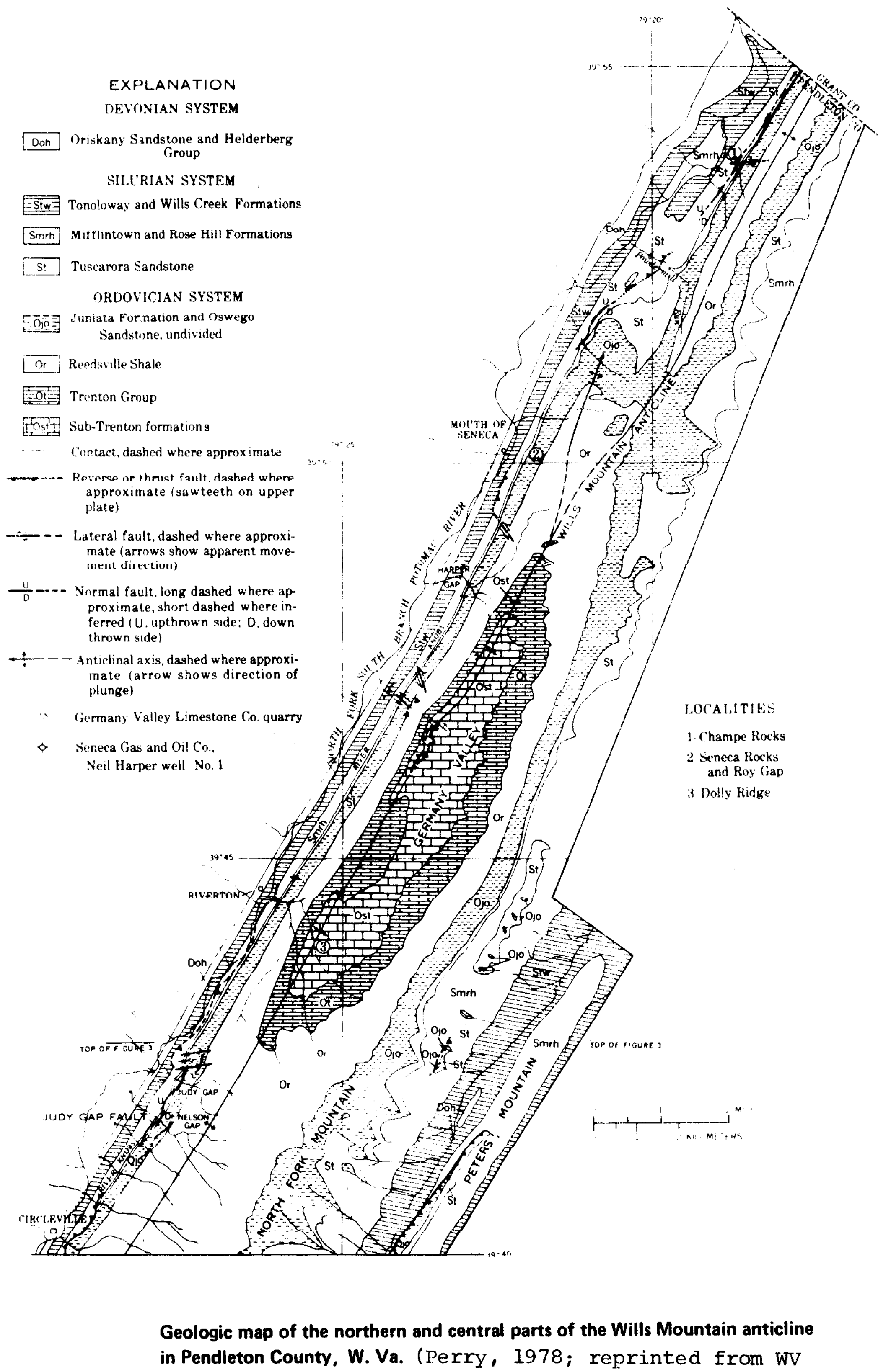
RAD, 1981

STOP 1. GERMANY VALLEY OVERLOOK

This stop is a panoramic view of the Wills Mountain anticline. Here in Pendleton County, the anticline exhibits its greatest culmination, and thus its greatest wavelength and amplitude. The fold crest here is entirely breached and the valley floor is composed of Ordovician Trenton and Sub-Trenton Formations (Figure 28). The surrounding resistant ridges represent the fold limbs, and are capped by the Silurian Tuscarora Sandstone. A "good feel" for the strong northwestward asymmetry of this fold can be obtained by noting the line of resistant hogbacks of vertical to overturned Tuscarora Sandstone along the northwest flank of the structure. We will be viewing this northwest limb in detail later.

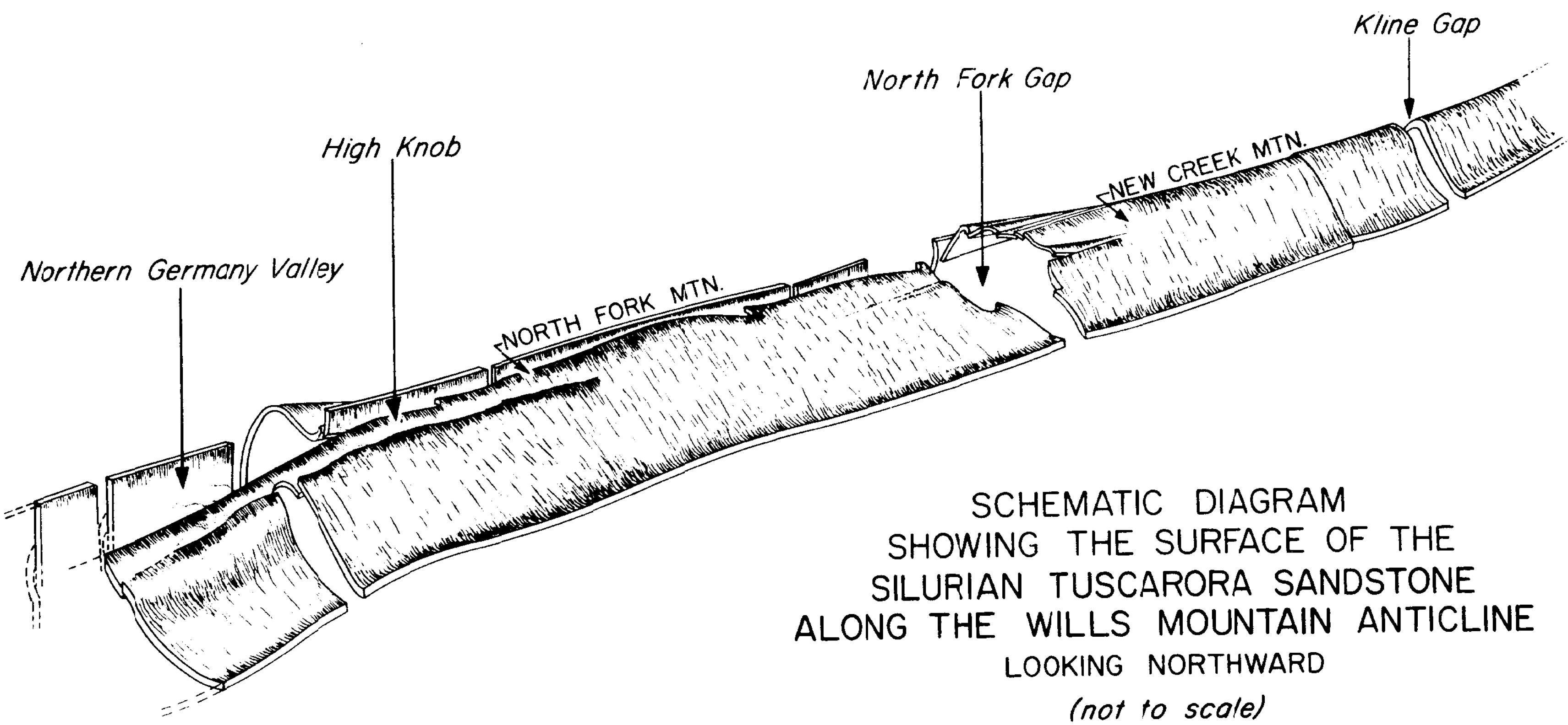
As we travel northeastward along strike, the anticline gradually plunges and thus decreases its wavelength and amplitude by 50 percent. The anticline has probably been breached due to differential weathering of crestal folding and faulting, of which a plunging remnant is visible at North Fork Gap (Figure 29). Continued chemical weathering of Middle Ordovician carbonates has helped produce the karsted Germany Valley along the culmination. From recollection, the fold at Greenland Gap is a simple anticlinal structure as opposed to what we see here. The structure also plunges from here southwestward into Virginia.

Also from this point can be seen the topographic and structural "Allegheny Front". The various topograpic foreknobs capped by the more resistant Upper Devonian and Mississippian formations can be seen along the front. The crest of the front is capped by the Lower Pennsylvanian Pottsville Sandstone.



Geologic map of the northern and central parts of the Wills Mountain anticline in Pendleton County, W. Va. (Perry, 1978; reprinted from WV Geological Survey RI No. 32)

Figure 28



SCHEMATIC DIAGRAM
SHOWING THE SURFACE OF THE
SILURIAN TUSCARORA SANDSTONE
ALONG THE WILLS MOUNTAIN ANTICLINE
LOOKING NORTHWARD
(not to scale)

FIGURE 29

SITES, 1978

STOP 2. NELSON ROCKS

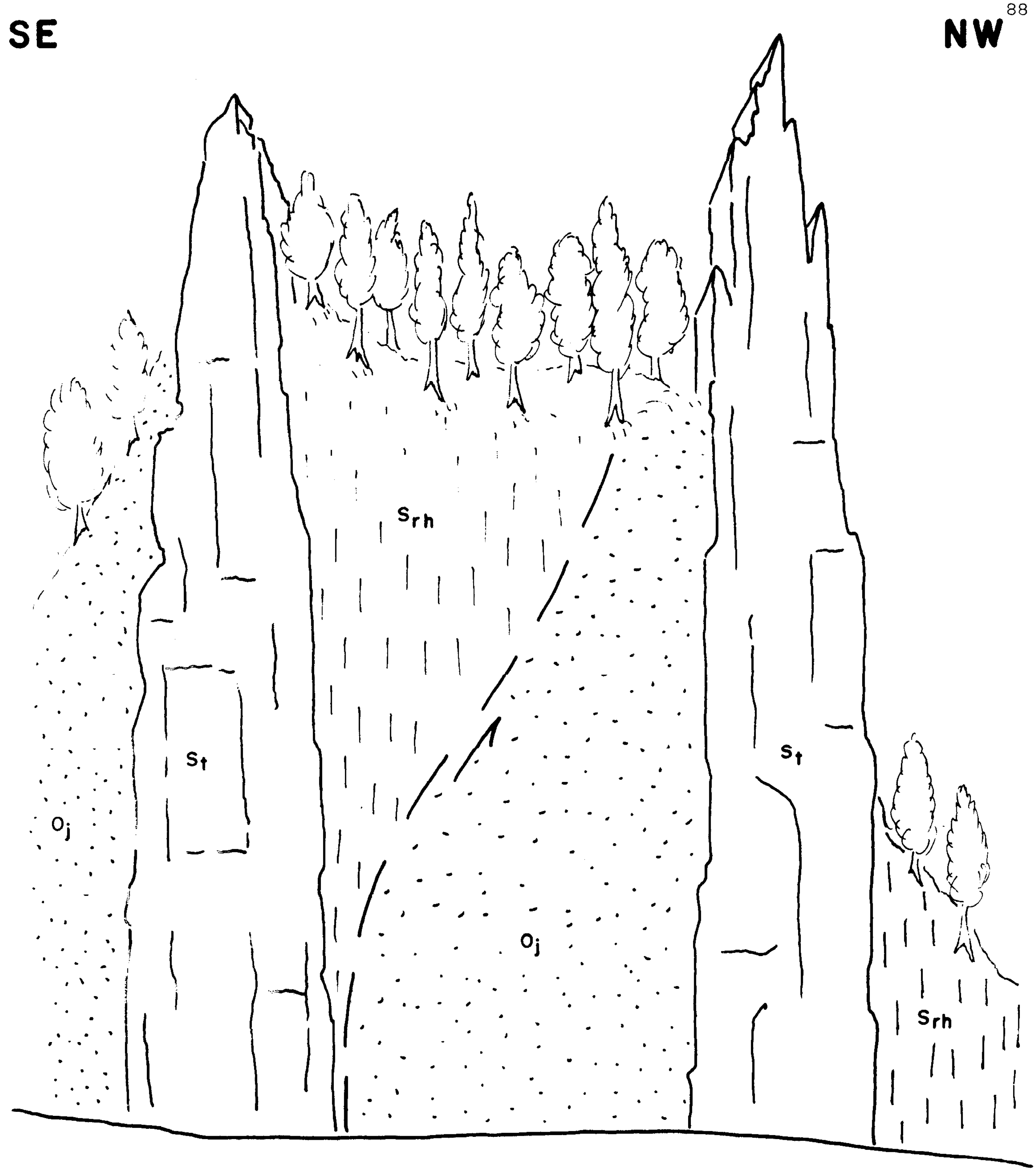
This is a most impressive exposure of the northwest limb of the Wills Mountain anticline, which we will be viewing along strike for most of the day. As exposed at Judy Gap, which we just traversed, Nelson Rocks are two very impressive resistant layers of Silurian Tuscarora Sandstone (Figure 30). Here the formation has been doubled, or repeated, by a pre-Wills Mountain northwest-dipping uplimb thrust fault (Perry, 1978). Between the vertical beds of Tuscarora are exposed Ordovician Juniata redbeds at stream level, and exposed toward the top of the ridge are Silurian Rose Hill shales (Figure 31).

These beds have since been rotated about the fold axis so that at present a steeply southeast-dipping fault with a "normal" sense of throw is observed.

As we travel northeastward along strike, note this phenomenon involving the Tuscarora Sandstone. Unlike Judy Gap, however, this gap at Nelson Rocks is not fault controlled. There are numerous tear faults associated with this steeply dipping northwest limb (Perry, 1971).

Doubled outcrop belt of Tuscarora Sandstone on the northern side of Nelson Gap, separated by the Judy Gap fault, which dips steeply to the right. (Perry, 1978; reprinted from WV Geological Survey RI No. 32)

Figure 30



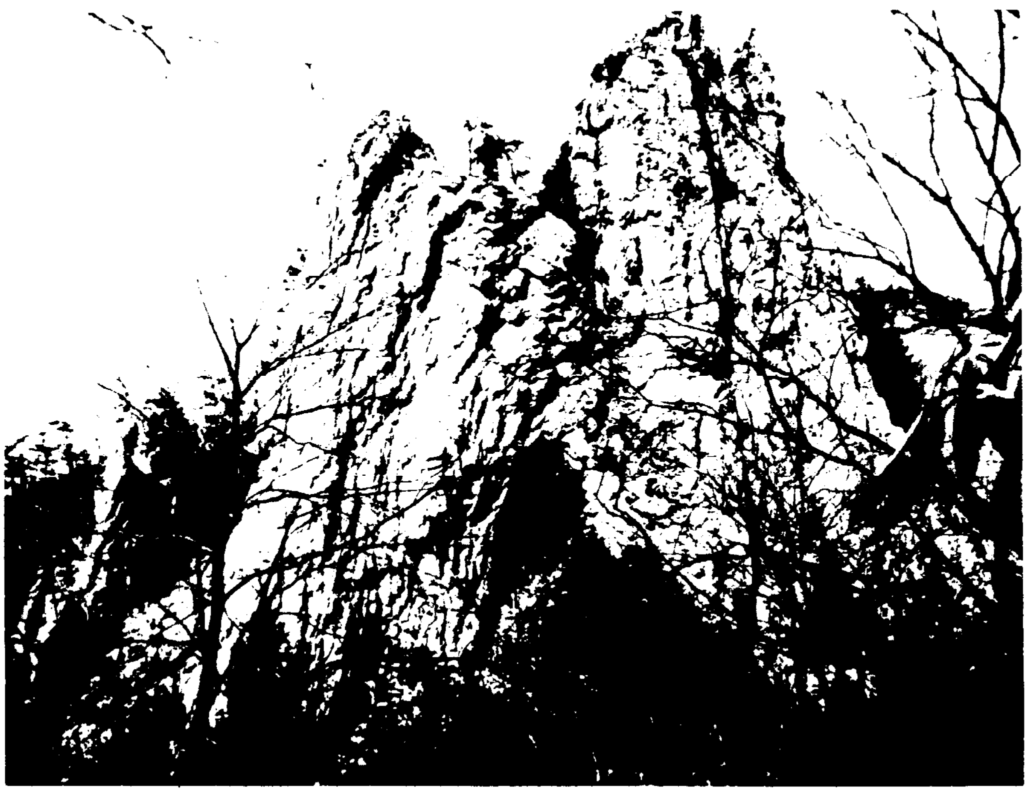
NELSON ROCKS

FIGURE 31

SITES, 1982

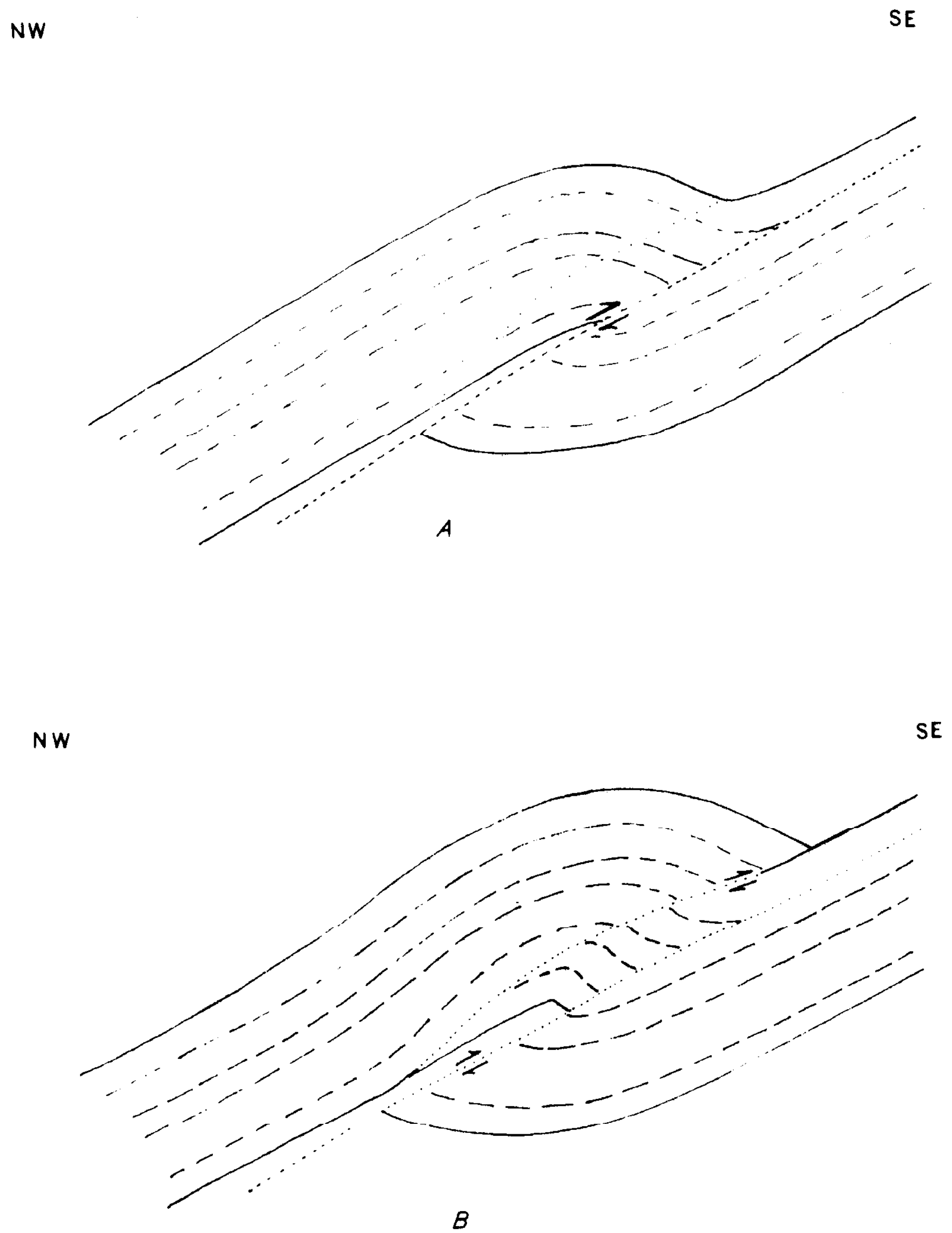
STOP 3. SENECA ROCKS

Seneca Rocks is perhaps the most impressive exposure along the northwest limb of the Wills Mountain anticline. When viewed from the highway, the rocks appear to show vertical bedding reflecting the simple northwest limb of the anticline. As we will see, there is a great deal of structure involved within that "vertically bedded" outcrop. Seneca Rocks is a hogback of Silurian Tuscarora Sandstone that exhibits the same pre-Wills Mountain, or at least early Wills Mountain structure as we have just observed at Nelson Rocks. Here the exposed structure involves only the Tuscarora Sandstone. There is drag-folding associated with the northwest-dipping thrust, which when viewed from the end-view of the rocks is referred to as the "Cathedral Arch" (Figure 32). Perry (1978) presents a diagrammatic sketch of the probable formation of this feature (Figure 33). As one will observe, the character of this northwest limb at the Tuscarora level appears to change along strike. Essentially, we are viewing the same early northwest-dipping uplimb thrust which exhibits varying amounts of forward motions along its length. This faulting eventually dies out prior to reaching the Greenland Gap section, which you have observed. It should be noted that this feature occurs only through this area of maximum culmination of the Wills Mountain anticline. Differential weathering along strike adds to the confusion.



Faulted fold in Tuscarora Sandstone, a side view of Seneca Rocks from the south.
(Perry, 1978; reprinted from WV Geological Survey RI No. 32)

Figure 32



Hypothetical stages of deformation of Seneca Rocks area: *A*. early stage, *B*. later stage.
(Perry, 1978; reprinted from WV Geological Survey RI NO. 32)

Figure 33

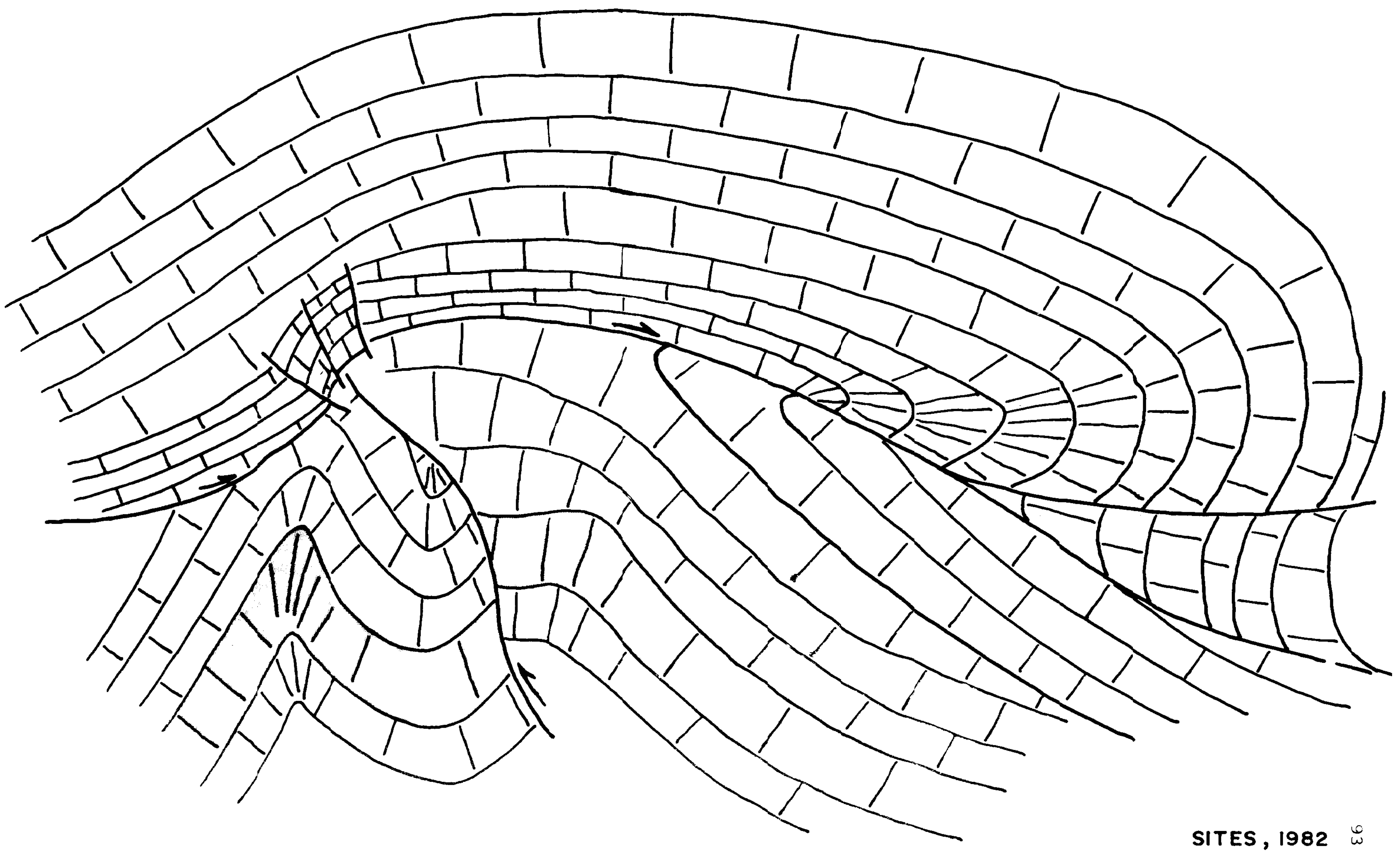
STOP 4. DOLLY CAMPGROUND

This locality is located along strike of the Walker Ridge anticline (New Creek Quarry and the Scherr Section) which we observed and discussed on the previous day. In this region it is termed the Hopeville anticline. Here the inner-core of the anticline can be observed, and is defined by the Lower Helderberg members (Figure 34). The structural connotation observed here is more complex than northeastward toward New Creek. Again, we feel this is related to the greater development of the Wills Mountain anticline within this region. At the Helderberg level, the crest of the fold is faulted out and overturned to the northwest. Fault planes are subhorizontal and further deformed implying continued post-Hopeville anticline deformation. This also implies additional east to west migration of deformation, at least within or across the Wills Mountain anticlinorium. The Cave Mountain anticlinal structures also imply this direction of deformation, rather than one from west to east. At the next stop we will observe the anticline at principally the Oriskany level in a regional setting.

DOLLY CAMPGROUND

FIGURE 34

SE NW



SITES, 1982

STOP 5. FRED HARMONS

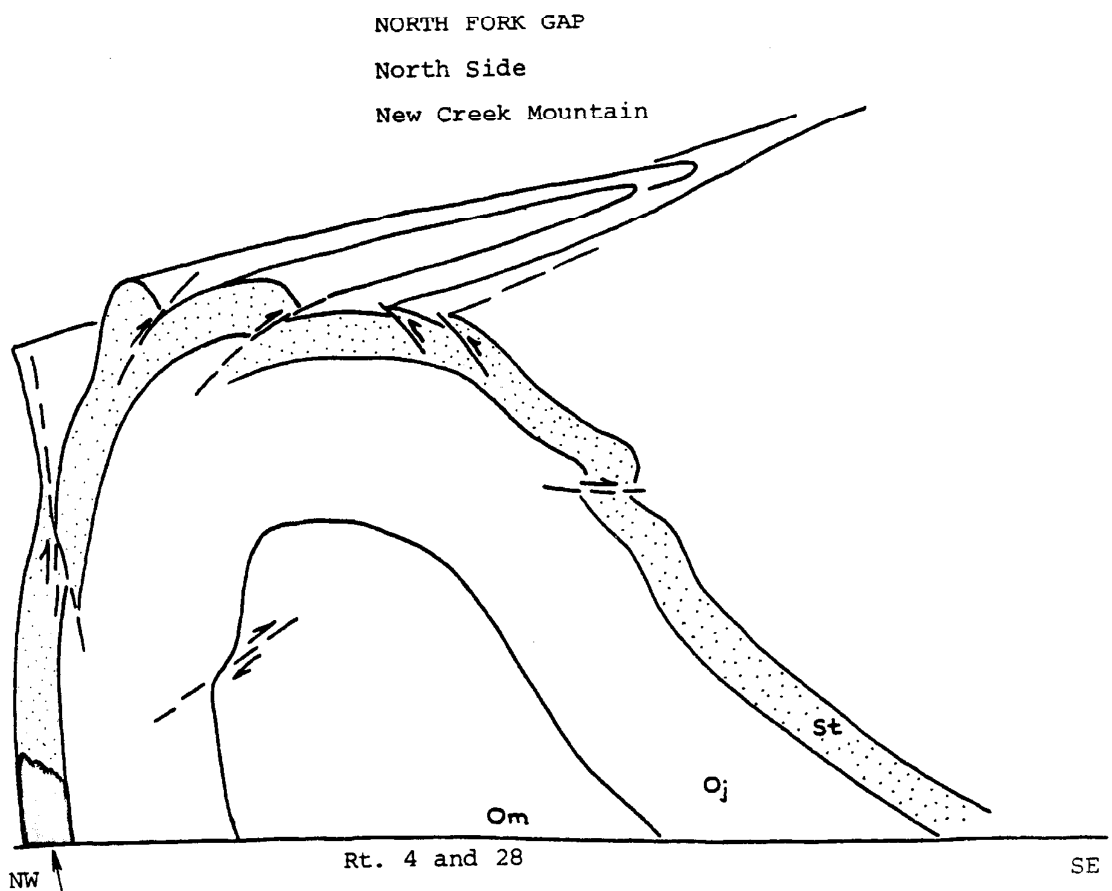
This is an excellent exposure showing the entire Hopeville anticline and its relationship to the Wills Mountain anticline. We will view the structure from river level and from an overlook. From these points the fold appears to show slight asymmetry to the southeast, which would be consistent if it were contained within a footwall block adjacent to major movement along the Wills Mountain anticline. Note the similarities between this locale, versus the others we have seen within this structural position along strike. Also, to the west we will be able to view the Allegheny Front.

STOP 6. WILDCAT ROCK

This exposure along strike is equivalent in structural position to Seneca Rocks. It is the northwest limb of the Wills Mountain anticline. Here the fold wavelength and amplitude has decreased in size by 50 percent. Unlike those exposures we have viewed earlier, there is not a complete double outcrop of Tuscarora. However, there is clearly visible pre-Wills Mountain anticline wedging exhibited within the exposed formation. The early northwest-dipping thrust has lost most of its stratigraphic throw at this point; although, there is still some reflection of the early-stage faulting found here in North Fork Gap. As the Wills Mountain anticline continues to plunge northeastward, the faulting within this northwest limb dies out (Figure 35).

Also exposed here are good examples of extension-faults (Perry, 1978). Extension-faults are sub-horizontal fractures with localized movement that compensate for the extension of bedded rocks when subjected to vertical or overturning rotation. These faults are clearly late-stage development along the steeply-dipping northwest limb of the anticline.

As we travel through North Fork Gap, take notice of the smaller breached portion of the crest, a result of northeastward plunge of a series of crestal-faults. Again notice the asymmetry of the gap profile; it is analogous to Greenland Gap. There is much structure exposed within this gap, but time will not allow us to observe it; some structures you will see as we travel through.



St= Tuscarora Ss.; Oj = Juniata Sh. and Oswego Ss.; Om= Martinsburg Fm. (not to scale)

Approximate position "Wildcat Rocks"

Figure 35

Sites, 1978

STOP 7. POWERS HOLLOW QUARRY

This particular stop is made to afford you the view of an actual thrust-fault and the changing nature of the drag along the hanging-wall. This quarry is located along the southeast flank of the Wills Mountain anticline, and exposes the Tonoloway Limestone of Silurian Age. The Middle member is repeated resulting in near doubling of the more massive, less argillaceous member, and thus the quarry. It should be noted that within the footwall block (now covered by recently quarried stone) the Middle member was exposed and contains a reefal build-up of massive stromatoporoids and tabulate and rugose corals. As at Pinto, algal stromatolites are also found within the Middle member. This Middle member "build-up" of Upper Silurian age is remarkably similar to patch-reefs within the Keyser Limestone of Lower Devonian age.

Appalachia

These mountains are deep,
deep, not high,
etched into the levelled plain of
the grandest peaks that ever stood
above a silent sea,
Sand castle mountains to a fretful Earth
tiring of her childs game of building
high as the sky
left to wash away
under millinia falling, like raindrops
on the sand.
We live in mountain roots exposed,
cut free of their own ancient heights
by wiggling, cutting, burrowing, sinking downward
search of water for the sea.
In the Sun-tipped valleys,
In the shadow of the hills,
In the shifting mists that hover and spread
above the water,
We are in the mountains,
following ever deeper down the canyons,
water,
returning to the sea.

\- Margaret McDowell

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APPENDIX

A DETAILED FIELD TRIP ROAD LOG

1982 APPALACHIAN GEOLOGICAL SOCIETY FIELD TRIP ROAD LOG

Prepared By

Katharine Lee Avary, West Virginia Geological & Economic Survey

DAY 1

Cumberland, Md. to Petersburg, W.Va.

Cumulative Distance (Miles)	Distance Between Points	Stops & Remarks
0.00	0.00	Holiday Inn, Cumberland. Go west on U.S. Route 48.
1.70	1.70	Use Exit 42 off U.S. Route 48, for U.S. Route 220 South.
2.00	0.30	End of exit ramp. Turn left onto U.S. 220 South.
8.30	6.30	Junction of U.S. 220 and road to Pinto. Turn left onto Pinto Road.
9.10	0.80	STOP 1 - Pinto - Railroad overpass. Go under overpass and uphill to left (north) and walk along railroad tracks.
9.90	0.80	Retrace route to U.S. 220. Turn left (south) on U.S. 220.
10.90	1.00	Slow down. Look back to north.
22.10	11.20	Turn left on road opposite Md. Route 135. Go 1 block.
22.15	0.05	Turn right.
22.50	0.35	Turn left.
22.60	0.10	Turn right. Road deadends at railroad tracks. STOP 2 - Queens Point - Walk down tracks to left.
22.90	0.30	Retrace route to U.S. 220. Turn left (south) on U.S. 220.
23.20	0.30	Maryland-West Virginia state line. Continue south on U.S. 220 through Keyser.
32.00	8.80	Junction of U.S. 220 and U.S. 50 at New Creek. Turn left (east) on U.S. 50/U.S. 220 and then left into quarry. STOP 3 - New Creek.

Cumulative Distance (Miles)	Distance Between Points	Stops & Remarks
32.30	0.30	Turn left (east) from quarry onto U.S. 50. East U.S. 220 south. Go up to top of hill and then turn around. Return to U.S. 220 North. Turn right (north) on U.S. 220.
34.75	2.45	Junction of U.S. 220 and Pine Swamp Road. (220/21). Turn left onto Pine Swamp Road.
36.30	1.55	Bear left onto dirt road.
37.15	0.85	Park bus in large open area. Walk up right-of-way to site of Columbia Gas-Mastellar #1 (Mineral 16). STOP 4 - Lunch Stop.
39.55	2.45	Retrace route to U.S. 220. Turn right on U.S. 220 South.
42.00	2.45	Junction of U.S. 220 South and U.S. 50 East. Stop 3 to left. Continue west on U.S. 50.
43.45	1.45	Junction of U.S. 50 and Ash Spring Run (dirt) road. Turn right (west) on dirt road.
44.20	0.75	Bear left on gravel road. Go through gate and up to STOP 5 - Columbia Gas-Pancake #1 (Mineral 37).
44.95	0.75	Retrace route to U.S. 50. Turn right (west) on U.S. 50.
46.20	1.25	Junction of U.S. 50 and W.Va. Route 93. Bear left on W.Va. 93 (south).
50.05	3.85	Mineral/Grant County line.
58.90	8.85	Junction of W.Va. 93 and Greenland Road at Scherr. Turn left onto Greenland Road.
59.00	0.10	Bear left and downhill onto Greenland Gap Road (92/3).
59.35	0.35	STOP 6 - Greenland Gap (Scherr Section) - Walk through section on north side of road, across from Fairfax Sand and Gravel Company operations.
59.80	0.45	Junction of Greenland Gap Road and Falls Road. Take road to Falls along Patterson Creek.
60.1	0.30	STOP 7 - Greenland Gap (Talus Slope) - Within Greenland Gap to overlook wedging and back thrusting of Tuscarora Formation.

Cumulative Distance (Miles)	Distance Between Points	Stops & Remarks
62.00	1.90	STOP 8 - Waterfalls (Falls) - On left (north) in Patterson Creek. Observe Oriskany.
62.20	0.20	Junction of Falls Road and Knobly Road. Take short jog to right (southeast) and then left, continuing southeast on road from Falls.
65.90	3.70	Junction with County Route 5. Turn right (southwest) onto Route 5 toward W.Va. Route 42.
74.30	8.40	Junction of Route 5, and W.Va. 42. Turn left (south) on W.Va. 42 toward Petersburg.
78.00	3.70	Junction of W.Va. 42 and W.Va. 28. Turn right (south) on W.Va. 28.
78.35	0.35	Turn left onto Grant County Hospital parking lot. Walk uphill toward water tower. STOP 9 - Fort Hill - Retrace route to W.Va. 28. Turn right (north) on W.Va. 28.
82.05	3.70	Junction of W.Va. 28 and W.Va. 42. Continue straight ahead toward Petersburg.
82.55	0.50	Junction of U.S. 220 and W.Va. 28 at traffic light in Petersburg. Turn left (north on U.S. 220.
82.75	0.20	Hermitage Motel on right. Overnight stop.

END OF ROADLOG FOR DAY ONE

DAY 2

Petersburg, WV to Franklin, WV

0.00	0.00	From Petersburg, go south on U.S. 220 approximately 17 miles. Just north of the village of Upper Trace, go across the bridge over the South Branch of the Potomac River. At the west end of the bridge, turn right onto Smoke Hole Road. The
17.00	17.00	detailed road log begins at this point.

Cumulative Distance (Miles)	Distance Between Points	Stops & Remarks
17.20	0.20	STOP 1 - Smoke Hole Entrance - Unload bus at old grist mill and walk 0.30 mile along road through the anticlinal structure.
17.50	0.30	
18.80	1.30	Silurian Tonoloway Limestone karst topography.
19.20	0.40	STOP 2 - Eagle Rock - Cave Mountain Gap. Unload bus and walk through section (0.40 miles).
19.60	0.40	
20.80	1.20	STOP 3 - Smoke Hole Cave - Walk through section.
21.20	0.40	South entrance to Monongahela National Forest Smoke Hole picnic area/campground. (May be gated).
21.90	0.70	North entrance to Smoke Hole picnic area/ campground. Lunch stop.
22.30	0.40	Y-intersection. (Shreve's store). Bear right on gravel road to Big Bend campground.
23.90	1.60	STOP 4 - Optional Stop - Mapledale Hollow - Bus can pull off to right for brief stop.
24.70	0.80	Bear left (uphill) toward Big Bend campground at Y-intersection.
25.80	1.10	Pendleton/Grant County line.
26.10	0.30	Parking lot, Big Bend campground. STOP 5 - Big Bend - Unload bus. Walk through edge of campground around the big meander in the South Branch of the Potomac River. Retrace route to junction with paved road at Shreve's store.
26.40	0.30	Grant/Pendleton County line.
29.80	3.40	Shreve's store junction. Turn right (uphill) on paved road.
30.30	0.50	Bear right on dirt road. (Paved road continues to left). Sign says Route 28 - 12 miles.
31.00	0.70	STOP 6 - Overlook - Pull off on right side of road for view into gorge. Turn around and retrace route downhill to paved road.
31.70	0.70	Junction with paved road. Turn left (downhill).

Cumulative Distance (Miles)	Distance Between Points	Stops & Remarks
32.20	0.50	Junction at Shreve's store. Bear right and retrace route to U.S. 220.
37.60	5.40	Junction of Smoke Hole Road and U.S. 220. Go south on U.S. 220 (straight ahead) toward Franklin.
49.10	11.50	Junction of U.S. 220 and U.S. 33 East. Stay on U.S. 220.
49.05	0.05	Thompson's Motel on right. Turn in to parking lot. Overnight stop.

END OF ROADLOG FOR DAY 2

DAY 3

Franklin, WV to Cumberland, Md.

0.00	0.00	From Thompson's Motel, turn left onto U.S. 220 North.
0.05	0.05	Turn left onto U.S. 33 West. Continue west on U.S. 33 over North Fork Mountain.
9.15	9.10	STOP 1 - Germany Valley Overlook - Pull off to right (north) of U.S. 33. View of Wills Mountain, the Allegheny Front, the Foreknobs, the River Knobs, Germany Valley. Return to U.S. 33 West.
13.15	4.00	Junction of U.S. 33 and W.Va. Route 28 at Judy Judy Gap. Turn left (south) on W.Va. 28.
13.75	0.60	STOP 2 - Nelson Rocks - Junction of W.Va. 28 and Nelson Gap Road (28/5). Bus can park on shoulder. Walk up road through gap and return to W.Va. 28. Turn around and retrace route W.Va. 28 North to junction with U.W. 33 at Judy Gap.
14.35	0.60	Junction of W.Va. 28 and U.S. 33. Bear left on W.Va. 28 North/U.S. 33 West toward Seneca Rocks.

Cumulative Distance (Miles)	Distance Between Points	Stops & Remarks
26.35	12.00	Junction of W.Va. 28 and U.S. 33 West. Roy Gap Road to right. Bus can park on shoulder on right. STOP 3 - Seneca Rocks - Group walks down Roy Gap Road, crosses suspension bridge, and walks up road to Tuscarora in gap. Walk back to bus. Turn around and go south on W.Va. 28/U.S. 33 East.
28.30	1.95	Hedrick's 4-U Motel on right (west) Turn into parking lot. Lunch stop. After lunch, turn left out of parking lot onto W.Va. 28 North/U.S. 33 West.
30.25	1.95	Junction of W.Va. 28 and U.S. 33 West at Seneca Rocks. Bear right on W.Va. 28. Go North towards Petersburg.
38.95	8.70	STOP 4 - Dolly Campground - Pull off to right (east). Continue north on W.Va. 28.
39.40	0.45	Pendleton/Grant County line.
42.10	2.70	STOP 5 - Fred Harmon's - Pull off to right (east). Continue north on W.Va. 28.
44.70	2.60	STOP 6 - Wildcat Rocks - Outcrop of Tuscarora on northwest limb of Wills Mountain anticline at west end of North Fork Gap. Pull off on right (south). Outcrop is on north side of W.Va. 28. Continue north on W.Va. 28.
47.55	0.30	Junction of W.Va. 28 and Route 28/6. Turn left on Rt. 28/6.
47.85	0.30	STOP 6 - Tonoloway Quarry - Active quarry in Tonoloway Limestone on right. Examine quarry face, then retrace route to W.Va. 28.
48.15	0.30	Junction of Rt. 28/5 and W.Va. 28. Turn left (north) on W.Va. 28.
52.90	4.75	Junction of W.Va. 28 and W.Va. 42 at west edge of Petersburg. Turn left on to W.Va. 42 North.
62.80	9.90	Village of Maysville. (Road to Falls to right).
70.30	7.50	Junction of W.Va. 42 and W.Va. 93 at Scherr. Bear right on W.Va. 93 North. (Greenland Road on right, which leads to Stop 6, Day 1).

Cumulative Distance (Miles)	Distance Between Points	Stops & Remarks
79.10	8.80	Grant/Mineral County line.
82.80	3.70	Junction of W.Va. 93 and U.S. 50. Bear right on U.S. 50 East.
86.40	3.60	Intersection of U.S. 50 and U.S. 220. Continue straight ahead on U.S. 220 North.
86.45	0.05	New Creek Quarry on right, Stop 3, Day 1.
92.05	5.60	Traffic light, south side of Keyser. Continue ahead on U.S. 220 North.
95.25	3.20	West Virginia/Maryland State line.
95.45	0.20	Road on right (east) leads to Queens Point, Stop 2, Day 1.
107.35	11.90	Road on right (east) leads to Pinto, Stop 1, Day 1. Continue ahead on U.S. 220 North.
109.15	1.80	Traffic light at Cresaptown, Md. Junction of U.S. 220 and Md. 53. Continue ahead on U.S. 220 North.
113.65	4.50	Junction of U.S. 220 and U.S. 48. Go east (right) on U.S. 48 toward downtown Cumberland.
115.55	1.90	Exit 43-C Holiday Inn, Cumberland, to left (north).

END OF ROADLOG FOR DAY 3