SECOND DAY

ROAD LOG, FRIDAY, SEPTEMBER 20, 1963

Mileage - 180.6 miles

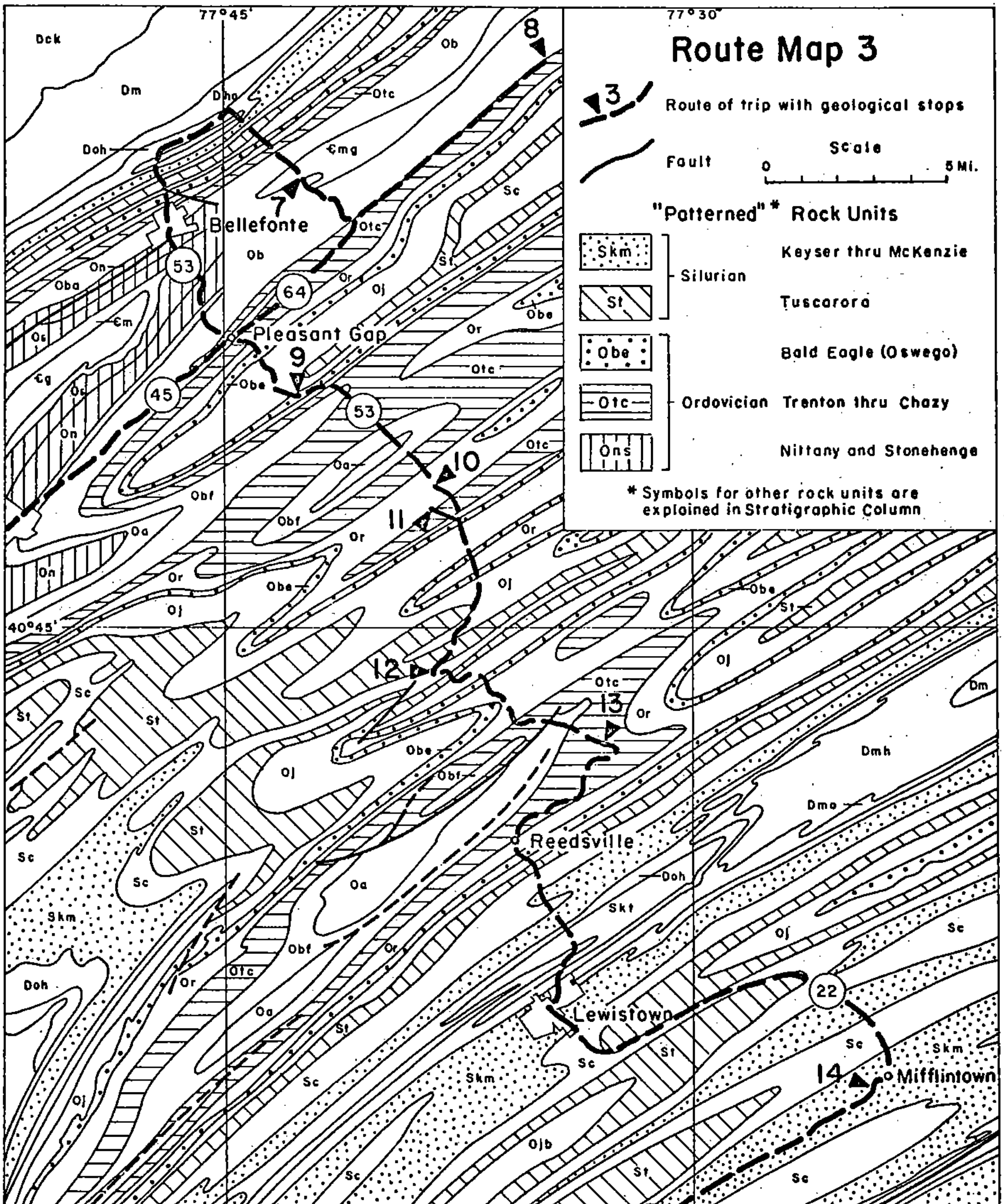
Buses will line up in parking space in front of Pollock Hall #5 for departure at 8:30 AM.

Mileage		
0.0		Mileage check begins at "Stop" sign in front of Pollock Hall #5. (Turn to Route Map 3.) TURN RIGHT.
0.1	0.1	Intersection. BEAR LEFT.
0.2	0.1	Penn State Nuclear Lab. Facility at 3 o'clock.
0.3	0.1	Stop sign. TURN RIGHT.
0.6	0.3	TURN RIGHT on Pa.-26 (North). This is the cloverleaf approach at the far end of overpass, to join Pa.-26 (North) heading toward Bellefonte.
0.9	0.3	Lower Ordovician Axemann limestone in road-cuts at 9 o'clock. Good view of Nittany Mt. at 2 o'clock. It is a synclinal mountain with the Oswego sandstone forming the resistant rim.
1.2	0.3	Centre Furnace at side of road at 9 o'clock.

CENTRE FURNACE

Here Cols. John Patton and Samuel Miles operated the first charcoal iron furnace in the region (1792-1809). Present stack was used from 1825 to 1855. In this era, Centre County led in the making of "Juniata iron."

1.3	0.1	Contact of Axemann limestone with Bellefonte dolomite. Route parallels strike of southeast dipping Bellefonte between Gatesburg Anticline (at 9 o'clock) and Nittany Mountain Syncline at 3 o'clock.


Route Map 3
Route of trip with geological stops
Fault
Scale
0
5 Mi.
"Patterned" * Rock Units
Skm
Keyser thru McKenzie
Silurian
St
Tuscarora
Obe
Bald Eagle (Oswego)
Otc
Ordovician
Trenton thru Chazy
Ons
Nittany and Stonehenge
* Symbols for other rock units are explained in Stratigraphic Column
77°45'
77°30'
40°45'
40°30'
Bellefonte
Pleasant Gap
Reedsville
Lewistown
Mifflintown
53
64
45
53
22
35
7
8
9
10
11
12
13
14

Mileage

2.3	1.0	Bellefonte dolomite in road-cuts on both sides of highway.
2.9	0.6	Crossing over Spring Creek.
3.8	0.9	Junction of Pa.-26 (North) with Pa.-64 (North). BEAR RIGHT and continue on Pa.-64 (North). Route continues in Bellefonte dolomite.
6.1	2.3	Front entrance of Rockview State Penitentiary. Buildings are underlain by the upper part of the Bellefonte dolomite which forms a subdued ridge within the valley.
6.7	0.6	Route parallels the contact between the Lower Ordovician Bellefonte dolomite and the Middle Ordovician Loysburg (Chazy) limestone. Loysburg limestone is at 9 o'clock, Bellefonte dolomite at 3 o'clock.
8.0	1.3	Standard Lime and Cement Company's Whiterock quarries (Middle Ordovician Limestone) at 3 o'clock.
8.1	0.1	Junction of Pa.-64 with Pa.-53. TURN LEFT on Pa. -53. Village of Pleasant Gap. Route proceeds northwest on Pa.-53 over the southeast flank of the Gatesburg Anticline.
8.6	0.5	State Fish Hatchery at 9 o'clock in Bellefonte dolomite.
9.1	0.5	East-dipping Axemann Limestone.
9.3	0.2	Nittany dolomite.
9.9	0.6	Village of Axemann, in Nittany dolomite.
10.3	0.4	Concealed contact between Stonehenge limestone and Nittany dolomite.
10.4	0.1	Stonehenge crops at 3 o'clock.
10.8	0.4	Stonehenge crops at 3 o'clock.
10.9	0.1	Cambrian Mines dolomite in cuts at 3 o'clock.
11.4	0.5	Crossing axis of Gatesburg Anticline.

Mileage

11.6	0.2	Gatesburg at 3 o'clock.
11.8	0.2	Outcrop of steep northwest-dipping Stonehenge limestone.
12.0	0.2	Entering Borough of Bellefonte.
12.1	0.1	Crossing the approximate trace of the Birmingham Fault, in Nittany dolomite.
12.4	0.3	Junction. Leave Pa.-53 and continuing STRAIGHT AHEAD to "Stop" at West Lamb Street.
12.7	0.3	"Stop" sign at West Lamb Street. TURN LEFT and proceed one block to "Stop" sign.
12.8	0.1	"Stop" sign. TURN RIGHT and continue to junction with Pa.-53 (West).
13.0	0.2	Junction Pa.-53 (West). Stop and proceed STRAIGHT AHEAD in Bellefonte dolomite.
13.2	0.2	Middle Ordovician limestone quarry at 3 o'clock.
13.4	0.2	Upper Ordovician Reedsville shale at 3 o'clock.
14.1	0.7	Upper Ordovician Oswego sandstone at 3 o'clock.
14.2	0.1	Upper Ordovician Juniata Formation at 3 o'clock.
14.5	0.3	The Lower Silurian Tuscarora sandstone can be seen high on the ridge of Bald Eagle Mountain at 8 o'clock, but is not apparent along the road.
14.7	0.2	Entering Borough of Milesburg.
15.2	0.5	Junction of Pa.-53 with U.S.-220. TURN RIGHT and continue on U.S.-220.
15.8	0.6	Bald Eagle Mountain on skyline at 12 o'clock paralleling highway is a Tuscarora-supported ridge. Low ridges at 9 o'clock are in Upper Devonian Harrell and Brallier shales and mark the base of the Allegheny Front.

Mileage		
17.7	1.9	Lower Devonian Helderberg limestone is to be seen in road-cut at 3 o'clock.
18.1	0.4	Lower Devonian Oriskany sandstone quarry at 9 o'clock.
18.2	0.1	TURN RIGHT on dirt road at northeast end of bridge. (Very tight turn for buses). Route proceeds south through Bald Eagle Mountain, following the drainage of Nittany Creek through Curtin Gap. We are moving up the west flank of the Gatesburg Anticline, passing through section from Lower Devonian Oriskany sandstone to Lower Ordovician Stonehenge limestone.
18.8	0.6	Crossing poor outcrop area underlain by Lower Devonian, Upper and Middle Silurian rocks.
19.8	1.0	Bridge over Nittany Creek.
20.1	0.3	Overturned Reedsville shale can be seen behind the shed at 3 o'clock.
20.2	0.1	Middle Ordovician limestone quarry at 9 o'clock; dip is 85° NE (overturned).
20.3	0.1	Junction with paved highway. Stop. TURN LEFT. Route parallels Middle Ordovician-Lower Ordovician contact.
20.6	0.3	Tree-covered hill at 2 o'clock, Sand Ridge, is upper Cambrian Gatesburg sandy dolomite and displays a typical Gatesburg outcrop and associated vegetation, referred to as "the barrens."
21.0	0.4	TURN RIGHT on unmarked paved road.
21.1	0.1	Bellefonte dolomite is in road-cut at 9 o'clock.
21.2	0.1	Nittany dolomite in road-cut at 3 o'clock is dipping 85° northeast (overturned).
21.3	0.1	Stonehenge limestone is dipping 85° northeast (overturned).
21.6	0.3	Stonehenge limestone outcrops in road-cuts.

Mileage

21.7 0.1 Lower Ordovician Stonehenge in contact with Upper Cambrian Mines-Gatesburg.

21.8 0.1 Mines dolomite crops out in road-cut at 3 o'clock. It is a gently dipping black oolitic dolomite; localized porosity development has been noted in this section.

22.0 0.2 Crossing Sand Ridge which marks the axis of the Gatesburg Anticline.

22.2 0.2 STOP VII. Group Leader - Dick Frost, Shell Oil Company. Follow group leader to observe crops of oolitic chert in the Mines dolomite, and quartzose and dolomitic sands of the Gatesburg Formation.

Approximately 125 feet of weathered dolomite are exposed here on the southeast flank of the Gatesburg Anticline. The outcrop is dominated by sparry oolite and fine-grained "relict?" dolomite, with interbeds of extremely fine dolomite (dolomitized lime mud). Approximately half of the exposure has intercrystalline and vuggy porosity. Oolitic chert, cross-bedded quartz sandstone, and intraformational conglomerates are present. Gatesburg sandstones crop out at the base of the exposure.

22.5 0.3 That was the last Cambrian exposure that we will se in the Nittany Arch region. We are now passing over Stonehenge limestone.

22.9 0.4 Stonehenge limestone is in road-cut outcrop at 9 o'clock. Route continues over weak outcrop area in the Beekmantown dolomite.

24.2 1.3 Entering the village of Zion. TURN LEFT at "Stop" sign onto Pa.-550 (North).

24.7 0.5 Junction of Pa.-550 with Pa.-64. Stop. Continue STRAIGHT AHEAD on Pa.-64 (North). Route continues along strike, in Beekmantown dolomite, roughly parallel to the Middle Ordovician contact at 3 o'clock.

Mileage

26.6	1.9	Cross road to Mingoville; continue STRAIGHT AHEAD.
28.7	2.1	Cross road to Hublersburg; continue STRAIGHT AHEAD on Pa.-64 (North).
29.4	0.7	Junction of Pa.-64 with Pa.-445; continue STRAIGHT AHEAD on Pa.-64.
30.0	0.6	Beekmantown dolomite outcrops in road-cut at 9 o'clock.
31.5	1.5	STOP VIII. Group leader - Dick Frost, Shell Oil Company. Follow group leader to observe well developed porosity in Bellefonte dolomite.

About 300 feet of section (near the top of the formation) are exposed 150 feet on the northwest side of the road, and 150 feet above this on the southeast side. Approximately 100 feet of this outcrop contain intercrystalline and vuggy porosity. Very fine to fine-grained dolomite with relicts of pellets, ooliths, and shells, is interbedded with extremely fine to sublithographic dolomite, and occasional limestones.

Retrace route and continue south toward Pleasant Gap via Pa.-64 (South).

38.2	6.7	Junction of Pa.-64 with Pa.-550. BEAR LEFT and continue on Pa.-64.
38.7	0.5	Route parallels the strike in Middle Ordovician limestone near the contact with the Lower Ordovician Bellefonte (at 3 o'clock). Oswego (Bald Eagle) sandstone holds up the Nittany Mountain (a syncline) at 9 o'clock.
40.9	2.2	Standard Lime and Cement Company rotary kilns can be seen at 3 o'clock.
42.8	1.9	Standard Lime and Cement Company's Whiterock Quarries at 9 o'clock.
43.2	0.4	Entering village of Pleasant Gap.

Mileage

43.7 0.5 Junction of Pa.-64 with Pa.-53. TURN LEFT and proceed southeast on Pa.-53 (South). Route will pass rapidly through weak exposures of Trenton Reedsville and Oswego (Bald Eagle) formations along the drainage of Gap Run. The center of Nittany Mountain Syncline (on this route) is occupied by the Upper Ordovician Juniata Formation.

46.0 2.3 Upper Ordovician Juniata road-cut exposures.

46.3 0.3 Tuscarora sandstone ridge on skyline at 10 o'clock marks axis of Nittany Mountain Syncline. A bit beyond the skyline the Clinton Formation is the youngest unit in the syncline.

46.8 0.5 STOP IX. Group leader - Dr. Richard P. Nickelsen, Chairman of the Department of Geology and Geography, Bucknell University.

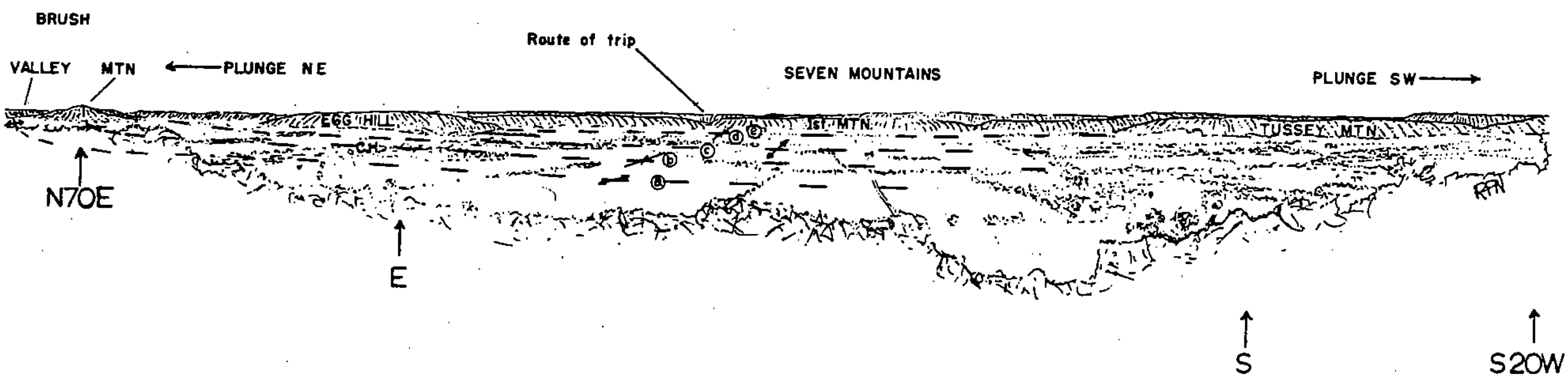
At lookout atop Nittany Mountain, follow group leader to observe the regional structure in Penn Valley. Elevation, 1809 feet. View is toward the southeast across Penn Valley to Seven Mountains (see Figure 5).

General

The floor of Penn Valley at approximately 1300 feet is the Harrisburg surface, developed upon folded Lower and Middle Ordovician carbonate rocks and upper Ordovician Reedsville shale. The Schooley surface is represented by synclinal and homoclinal ridges of Ordovician Oswego (Bald Eagle) sandstone and Tuscarora sandstone such as Egg Hill, Brush Mountain, and the complex of ridges in the Seven Mountains area. These ridges have summit elevations of 1800-2000 feet. Beneath your feet is the outcrop belt of the Oswego or Bald Eagle sandstone. Outcrops of this unit containing quartz, chert, and metamorphic rock pebbles are present across the road and extend downhill toward Centre Hall.

Structure

The purpose of this stop is to acquaint you with two of the major structural units of the region that the field trip will cross--the Penn Valley Anticlinorium and the Seven



STOP IX NITTANY MTN. ABOVE CENTRE HALL (1809')

View toward southeast across Penn Valley anticlinorium to Seven Mountain synclinorium.

a. axial trace of anticline through Brush Valley and Centre Hall

b. axial trace of Brush Mountain syncline

c. axial trace of anticline between Old Fort and Centre Hall

d. axial trace of Egg Hill - Tussey Mountain syncline

e. approximate position of anticline between Egg Hill - Tussey Mountain syncline and First Mountain (Axial trace not indicated on sketch)

C.H. - Centre Hall

Figure 5

Mountain Synclinorium. At this latitude the Nittany Arch of Butts and Moore (1936, p. 79) is separated along strike into two anticlinoria by the Nittany Mountain Syncline. You are standing on the southeast flank of the Nittany Mountain Syncline looking across the southeast half of the Nittany Arch, the Penn Valley Anticlinorium, a first order anticlinorium of this region. Second order anticlines and synclines comprising the Penn Valley Anticlinorium are labeled "a," "b," "c," "d," and "e" on the sketch for Stop IX (Figure 5). Topographic expression of structure is present wherever resistant stratigraphic units such as the Tuscarora and Bald Eagle sandstones are present in synclines beneath the Schooley surface. Examples are the Nittany Mountain Syncline, the Brush Mountain Syncline and the Tussey Mountain-Egg Hill Syncline. Egg Hill is present because a sag, or northeast plunge, in the southwest-plunging axis of the Tussey Mountain-Egg Hill Syncline has locally brought Bald Eagle sandstone beneath the level of the Schooley surface.

Ridges in the Seven Mountains area are all developed on Tuscarora or Bald Eagle sandstone while valleys are underlain by Silurian Rose Hill shale or Ordovician Juniata Formation and Reedsville shale. The Seven Mountains is structurally a complex first order synclinorium, and is the result of the up-plunge manifestation of the synclinoria of the Broad Top Coal Field to the southwest and the Northern Anthracite basin to the northeast. It is bounded on the southeast by the Kishacoquillas Valley Anticlinorium which brings Ordovician carbonate rocks to the surface.

The route of the trip to the south across Penn Valley, the Seven Mountains, and Kishacoquillas Valley will follow approximately the nearly north-south axis of the culmination of the Pennsylvania salient of the Central Appalachians. Fold axes to the east and northeast of this culmination typically plunge northeast into the anthracite coal fields, whereas fold axes to the south and southwest plunge southwest. Examples of both plunges are to be seen from this vantage point:

1. The Tussey Mountain synclinal nose is developed on a southwest-plunging syncline;

2. The Brush Mountain synclinal nose is developed on a northeast-plunging syncline;

3. Penn Valley bifurcates to the northeast into two valleys developed upon northeast-plunging anticlines;

4. The axial sag responsible for the preservation of Egg Hill as an isolated erosional remnant of Bald Eagle sandstone probably results from conflict between northeast and southwest plunges in this area.

Mileage

Route continues through Juniata Oswego (Bald Eagle), Reedsville and Trenton formations on the east flank of Nittany Mountain Syncline.

47.7 0.9 Entering the Borough of Centre Hall located on the northeast-plunging nose of Penn Valley Anticline and on the Bellefonte dolomite.

48.1 0.4 Junction with Pa.-192 (East). Continue STRAIGHT AHEAD on Pa.-53. Route continues on east flank of Penn Valley Anticline in Middle Ordovician limestone.

49.0 0.9 Cross synclinal axis in Middle Ordovician Trenton limestone.

49.3 0.3 Junction of Pa.-53 with Pa.-45 at Old Fort.

POTTER'S FORT

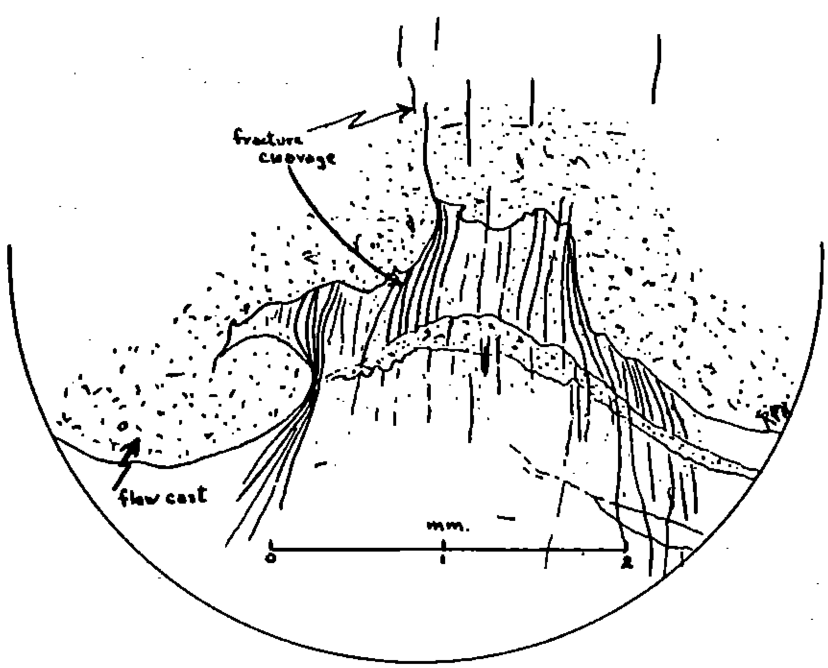
Built in 1777 by General James Potter.
A stockaded fort refuge for the settlers of the valley region.

Continue straight ahead, riding on Black River, Chazy limestones.

49.8 0.5 Approximate contact with Bellefonte dolomite.

Mileage

50.6	0.8	Cross minor anticlinal axis; Axemann limestone is exposed in core.
51.3	0.7	Middle Ordovician Trenton limestone can be seen in road-cut at 3 o'clock.
51.5	0.2	Egg Hill at 9 o'clock. A synclinal topographic high, with Oswego (Bald Eagle) sandstone in the core.
51.6	0.1	Reedsville shale at 3 o'clock.
52.0	0.4	STOP X. Group leader - Dr. Richard P. Nickelsen, Bucknell University. Follow group leader to observe Reedsville shale in Tussey Mountain-Egg Hill syncline.



STOP X

Camera lucida sketch of Reedsville shale from Tussey Mountain-Egg Hill syncline, showing sandstone flow casts and fracture cleavage.

Figure 6

General

This stop, in flat-lying, interbedded, shale and graywacke sandstone of the Reedsville formation in the trough of the Egg Hill-Tussey Mountain Syncline, a Second order feature, was planned to demonstrate the character of small-scale structures in a simple structural setting. The accompanying camera lucida sketch (Figure 6) of a thin section cut perpendicular to the cleavage-bedding intersection shows fracture cleavage and flow-casts at a sandstone-shale contact.

From the upper part of the exposure, the nose of the southwest-plunging Tussey Mountain Syncline may be seen.

Description of Outcrop

Small scale structures to be seen here are horizontal bedding, vertical fracture cleavage, vertical cross-joints perpendicular to the cleavage-bedding intersection, and flow-casts and other sole marks on the bottoms of sandstone beds. Cleavage-bedding intersections are emphasized by excellent development of "pencil shales", where elongated, pencil-like, fragments produced by cleavage-bedding intersections are aligned parallel to the fold axis. Cleavage and bedding also provide the fractures favoring the development of the spheroidal weathering present throughout the outcrop.

The bottoms of many thin sandstone beds and laminae show small scale (1 - 2 mm.) flow-casts which indent the tops of the underlying shale beds and appear to be tectonically oriented parallel to the strike of fracture cleavage or fold axes. The fracture cleavage appears in thin section as fine, dark, irregular lines, spaced at intervals of .05 to .2 mm. Micas, clays and tabular quartz grains are oriented in their original sedimentary position with long axes parallel to bedding. No discernible minerals have developed in the plane of the cleavage. This cleavage fits the definition of fracture cleavage in that it is a spaced cleavage, not paralleled by mineral orientation. The rock cannot be split into cleavage flakes less than the thickness of the cleavage slices and the only mineral orientation is a relic of the original sedimentary orientation. Cleavage has been compressed and bent around flow-cast projections on the base of the sandstone beds as shown in the camera lucida sketch. I believe that this indicates that cleavage has developed perpendicular to the principal stress axis operating

NW - SE parallel to bedding during a period of flattening which may have been initiated prior to folding. The apparent tectonic orientation of flow-casts (parallel to fold axes and shale pencils ?) suggests that the flattening may have been initiated while the sediments were in a soft state. The cleavage may have begun forming at this time and developed its present character during succeeding lithification of the sedimentary sequence. More work is needed here to clarify the origin of this cleavage. Work by Maxwell (1962) on origin of cleavage in Martinsburg slate of northeastern Pennsylvania has indicated a similar early development of cleavage.

Summary

Important features of this outcrop are:

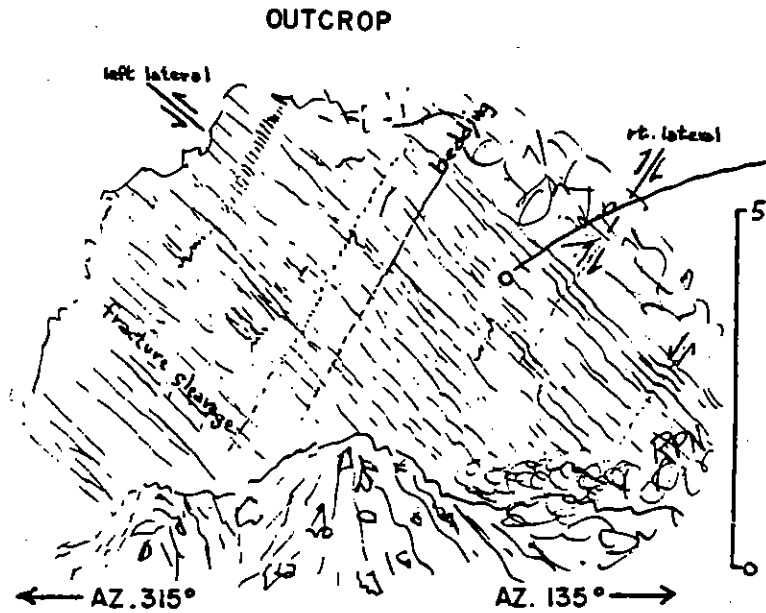
1. Cleavage is preserved in its initial attitude, perpendicular to bedding, and has undergone no internal or external rotation as a result of later folding. Neither has it served as a plane of differential slip. This outcrop thus represents what I infer to be the initial state of cleavage in the area.

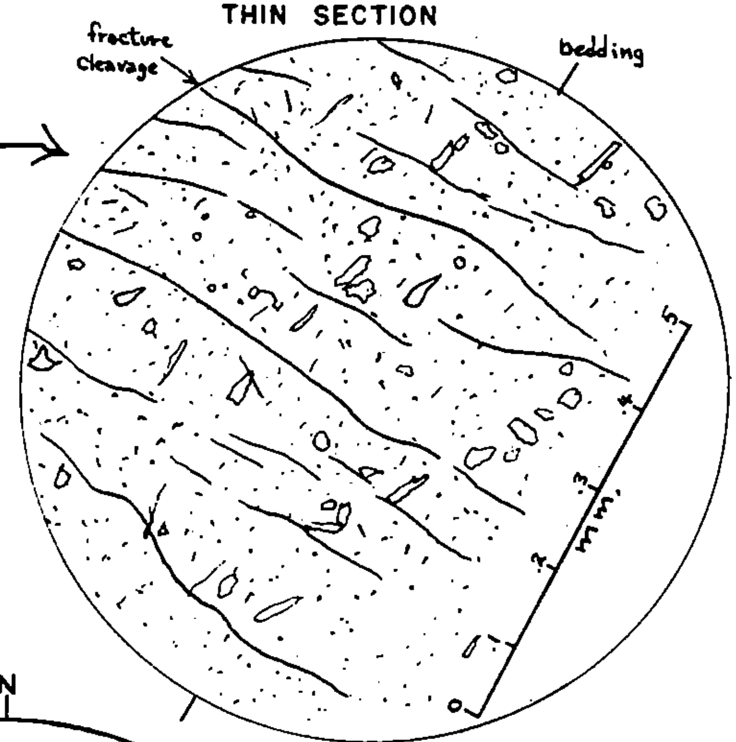
2. Fracture cleavage in shales throughout the region appears under the microscope as it does in this outcrop.

3. Cleavage is interpreted as having developed perpendicular to the greatest principal stress axis as indicated by compression and bending of cleavage against sandstone flow-casts.

4. Relations between sandstone flow-casts along the base of sandstone beds and cleavage suggest that cleavage may have been initiated before complete lithification of the sediment.

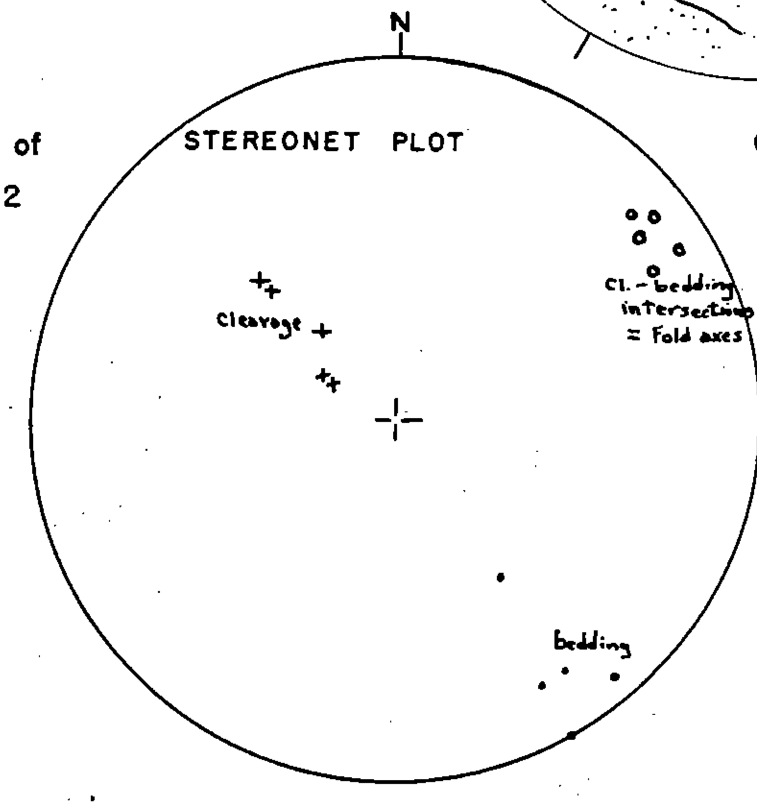
5. The composition and significance of the dark matter along cleavage planes is unknown at the present time.





STOP XI

Outcrop of Antes Gap member of Reedsville shale along Route 322 south of Potters Mills.



CLEAVAGE ∧ BEDDING

68°; 72°; 65°; 68°; 52°

Figure 7

Mileage

52.5 0.5 Reedsville shale outcrop in cut at 9 o'clock.

52.8 0.3 Entering village of Potter Mills. Extremely tightly folded anticline in the Trenton limestone can be seen at 8 o'clock near bridge over Potter Stream.

This anticline is core of the structure exposed at STOP XI ahead.

53.4 0.6 Junction of Pa.-35 with U.S.-322. TURN RIGHT and proceed on U.S. 322.

54.2 0.8 STOP XI. Group leader - Dr. Richard P. Nickelsen, Bucknell University.

Follow group leader to view excellent development of fracture cleavage in a tight anticline of Reedsville shale.

General

This exposure is in the Antes Gap Member of the Reedsville shale on the northwest limb of the tight anticline (Second order) exposed at 52.8 miles. Features to be seen here are well-developed fracture cleavage, shear folding, obscure bedding, and bending of cleavage along certain bedding planes. (See sketch for STOP XI-Figure 7).

Description of Outcrop

At this exposure the incompetent, black, clay shale of the Antes Gap Member shows perhaps the best developed fracture cleavage of the region. Fracture cleavage, dipping 25 to 55 degrees southeast, is the most prominent structure in the outcrop. Bedding dips vertically to steeply northwest. This outcrop is important for the following reasons:

1. It has not been folded predominantly by concentric folding with slip between bedding planes. The bedding planes are merely passive designs and have not served as important slip planes. Rather the Antes Gap Member has deformed by shear folding with slip along fracture

cleavage planes across bedding planes. Such folds are not generally developed in the central Appalachians west of the Blue Ridge and Great Valley.

2. Fracture cleavage is no longer perpendicular to bedding because bedding has been internally rotated by left-lateral* affine slip along fracture cleavage planes (*left-lateral sense of slip when viewed as in sketch of outcrop for Stop XI).

3. Fracture cleavage viewed microscopically appears similar to fracture cleavage of Stop IV except that it is no longer perpendicular to bedding. It has served as a slip plane along which bedding has been internally rotated. Tabular minerals have <u>not</u> been rotated out of their initial bedding attitude; cleavage is spaced similarly and shows no discernible parallel mineral orientation.

4. Certain bedding planes <u>have</u> served as planes of right-lateral and left-lateral slip with the result that cleavage planes are warped in places. Right-lateral bedding slips are most abundant and are evidence of some small-scale concentric folding in a section which is being deformed predominantly by shear along fracture cleavage planes. The fact that both shear and concentric folding are represented here would seem to be good evidence that the two kinds of folding are transitional, the importance of one or the other being a function of lithology and structural position. The Antes Gap shale in this particular tight anticline is probably the only lithic unit that is undergoing appreciable shear folding in the whole Ordovician section. The same shale in adjacent broad anticlines and synclines show no evidence of appreciable slip along cleavage planes.

<u>Summary</u>

This somewhat anomalous outcrop shows excellent fracture cleavage and obscure bedding as well as evidence of shear folding with minor concentric folding. The best evidence for shear folding is the lack of a right-angle relationship between cleavage and bedding, indicating internal rotation of bedding planes along cleavage. Most important, the outcrop demonstrates the ultimate development of small-scale and continuous processes of deformation in the central Valley and Ridge Province.

Mileage

Continue AHEAD to first junction.

54.4	0.2	At junction, make a U TURN and return to intersection with Pa.-35.
55.4	1.0	Junction of Pa.-35 with U.S.-322. Proceed STRAIGHT AHEAD on U.S.-322. Reedsville outcrop is in bank at 3 o'clock (dip is to the southeast).
55.6	0.2	Entering State Forest Lands - Seven Mountains Area.
55.7	0.1	Talus blocks of Oswego (Bald Eagle) sandstone may be seen at 3 o'closk.
55.9	0.2	Juniata Formation exposed in long road-cut at 3 o'clock - this is near axis of small anticline.
56.3	0.4	Upper Ordovician Oswego (Bald Eagle) conglomeratic sandstone is exposed at 9 o'clock.
56.6	0.3	Reedsville shale crops out at 9 o'clock.
56.9	0.3	State Forestry Experiment Station at 9 o'clock.
57.6	0.7	Oswego sandstone float is to be seen in cuts at 9 o'clock.
58.2	0.6	Juniata crops out at 3 o'clock on small southwest plunging syncline.
58.7	0.5	Mifflin County line.
59.2	0.5	Juniata Formation exposures are obvious at 9 o'clock (rather steep southeast dip).
59.4	0.2	Contact of Juniata Formation with Tuscarora sandstone occurs at 3 o'clock.

Mileage

59.9 0.5 Southeast-dipping shaly beds in the upper part of the Tuscarora sandstone are exposed at 3 o'clock.

60.6 0.7 Hairpin curve is on the axis of a tight syncline developed in an outcrop-belt of Rose Hill shale.

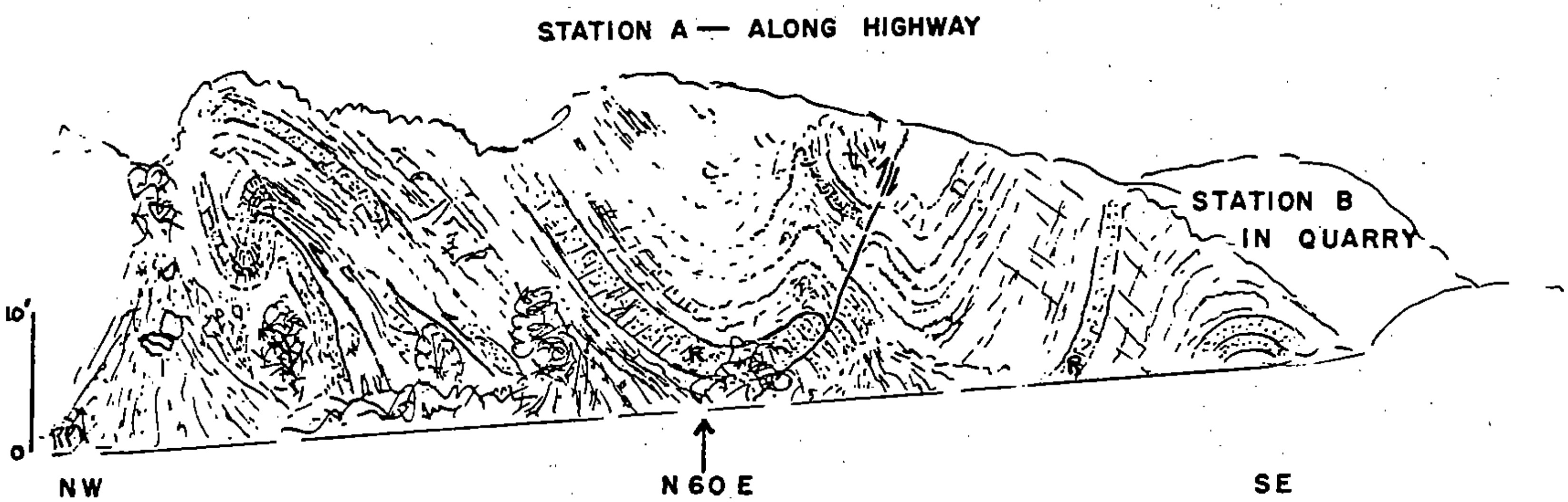
61.1 0.5 STOP XII. Group leader - Dr. Richard P. Nickelsen, Bucknell University. Park as far off the highway as possible beyond the east end of the bridge over Laurel Creek. This is a high-speed, heavily traveled road, so please exercise EXTREME CARE and good judgment by staying off the road. Follow group leader to study minor structures and folds in tight syncline developed in the upper Tuscarora-Castenea sandstone and the basal Rose Hill shales.

General

This exposure lies on the axis of the southernmost syncline (second order) in the Seven Mountains Synclinorium. Ridges held up by Tuscarora sandstone on opposite limbs of the strucutre rise to north and south. Rocks in the outcrop include the uppermost Tuscarora (or Castenea) red, hematitic sandstone and the basal Rose Hill shale. The stop has been divided into two stations: Station A (see Figure 8), along the highway, shows complexly folded and faulted interbedded sandstone and shale; Station B, in a small quarry off the road, shows fine development of minor structures and flowage in shales of the Rose Hill Formation. Parts A and B of the exposure thus illustrate respectively competent folding and incompetent deformation in the same tectonic setting.

Description of Outcrop

Station A (see Figure 9) shows several third or fourth order folds and associated faults developed here in the tightly squeezed trough of the large second order syncline. It is typical of the axial crowding that may be expected in such structures in this area. It should be



STOP XII

Outcrop of Tuscarora-Castanea sandstone and Rose Hill shale along Route 322 in Seven Mountains area.

Figure 8

emphasized that the complex structures shown here are by no means typical of what is usually seen in broad folds and on fold limbs in this area.

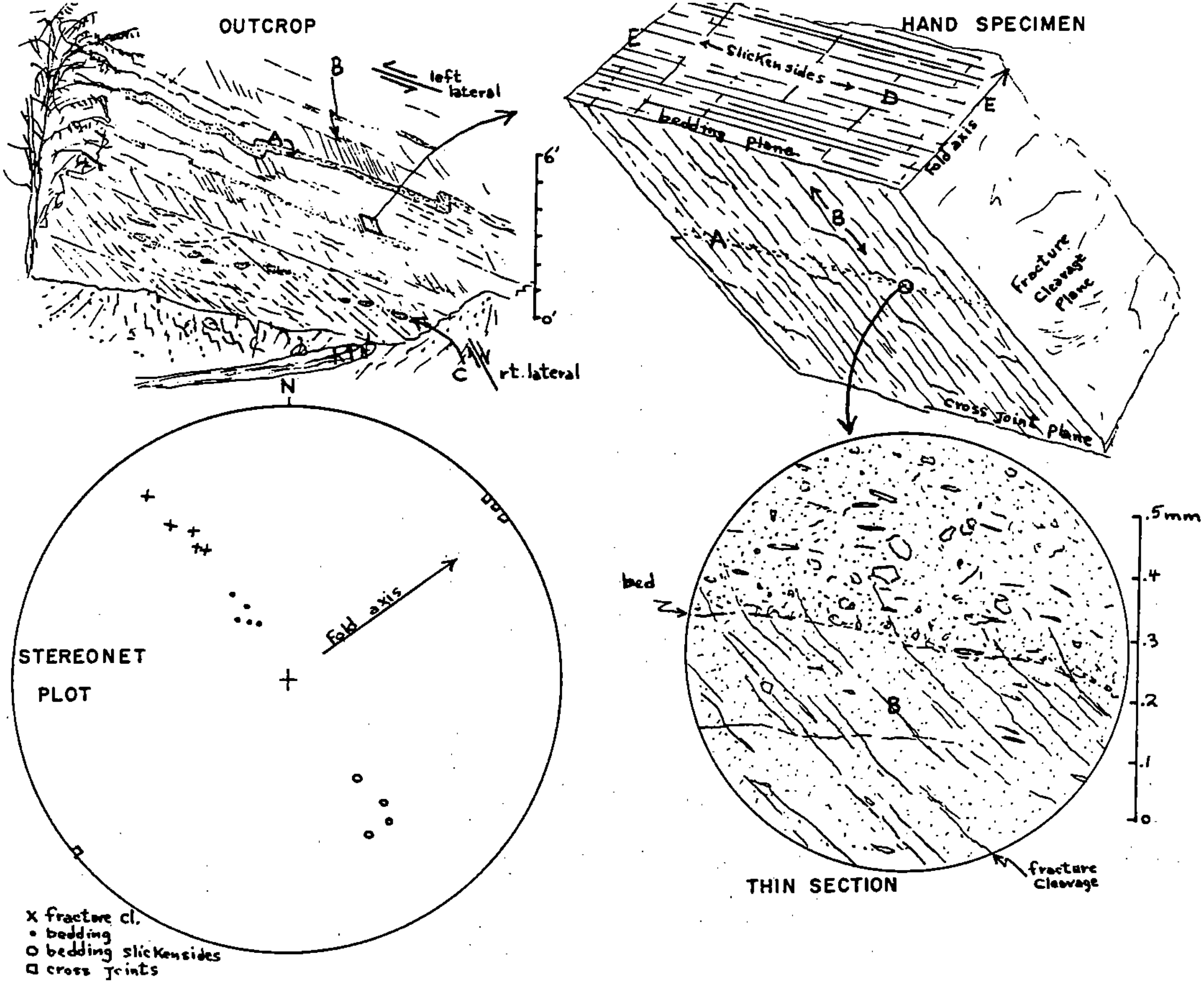
Bent sandstone beds show joints and fracture cleavage parallel to axial planes of folds in the fold hinges but fanning nearly perpendicular to bedding on the limbs. Shaly beds show fracture cleavage more nearly parallel to axial planes on both hinges and limbs of folds. Most bedding planes show slickensides denoting bedding slip during concentric folding. Such bedding slip is probably responsible for internally rotating fracture cleavage from its original attitude perpendicular to bedding to its present attitude, intersecting bedding at less than 90^{o} on fold limbs. The intense folding of the competent units in this part of the exposure contrasts with the simple structure and extensive intra-bed flowage to be seen at Station B.

Station B (see Figure 9) shows unusually good development of small-scale structures which illustrate the essential small-scale deformation mechanisms of the region. Rarely are these structures as well developed as in this outcrop and at Stop XI, and their strong development here must be ascribed to the extreme squeezing in the trough of the second order syncline.

Small-scale structures to be seen are:

A) bedding with parasitic or "drag" folds,
B) fracture cleavage intersecting bedding at less than 90^{o},
C) sandstone boudins in "plastically" deformed shale,
D) bedding slickensides oriented perpendicular to bedding-cleavage intersections, and
E) bedding-cleavage intersections parallel to fold axes.

(Letters are keyed to sketch, Figure 9, for Stop XII, Station B.)



STOP XII — STATION B

Outcrop of Rose Hill shale in small quarry off Route 322 in Seven Mountains area.

Figure 9

Deformation by differential slip among two different sets of planes has occurred in this outcrop. Between bedding planes, particularly at sandstone-shale contacts, there has been left-lateral slip congruent with the normal bedding slip on the limb of a fold. The direction of slip is shown by bedding slickensides. Within shale beds both right- and left-lateral slip has occurred along fracture cleavage planes. Right-lateral slip dominates but left-lateral slip occurs in the vicinity of small parasitic folds. The amount of "plastic" deformation accomplished by the fracture cleavage-slip mechanism is well illustrated by the sandstone boudins in the thick shale bed at the base of the outcrop. They appear to represent the vestige of a once-continuous sandstone bed which has been pulled apart and now "floats" as a number of isolated boudin fragments in the surrounding "plastically" deformed shale. Further evidence of "plastic" deformation is provided by deformed brachiopods from shaly beds.

Summary

At this stop an opportunity is provided to compare and contrast the deformation of a competent-incompetent interbedded sequence (Station A) with a predominantly incompetent sequence (Station B) under the same stress environment. In the competent sequence, concentric folding and faulting is the predominant mechanism of deformation but shales show some flowage parallel to fold axial planes along fracture cleavage. In the incompetent sequence distinct beds show bedding plane slip, an expression of concentric folding, but shales have been deformed internally along fracture cleavage planes in a manner similar to the shear folding at Stop XI. The amount of internal "flowage" is shown by sandstone boudins and deformed fossils. The cleavage-bedding angle is considerably less than 90^{o} and results from the interplay of two affine slip mechanisms affecting cleavage and bedding. It is entirely possible the cleavage did not start perpendicular to bedding but, on the basis of relations in less deformed localities (e.g., Stop X), I believe that it did. The slip mechanisms, visible in this outcrop, which probably played a role in changing the cleavage-bedding angle are:

a) left-lateral internal rotation by slip between bedding planes which tends to rotate cleavage in a counterclockwise direction,

b) predominantly right-lateral internal rotation between fracture cleavage planes which tends to rotate bedding in a clockwise direction.

Added to these rotations is the external rotation of the whole fold limb which rotates cleavage and bedding in a clockwise direction but does not change their angle of intersection except to the extent that it reorients the cleavage and bedding with respect to regional principal stress axes.

<u>Mileage</u>

61.3	0.2	Loose blocks of Tuscarora sandstone are exposed on southeast limbs of a syncline; dip in this area is nearly vertical to overturned.
61.4	0.1	Juniata Formation at 9 o'clock dips to the south (overturned) on the south limb of a syncline. Route continues along strike of beds.
62.1	0.7	Juniata Formation at 9 o'clock.
62.3	0.2	Leaving Seven Mountains area.
62.4	0.1	Oswego (Bald Eagle) sandstone at 9 o'clock across the road from American Legion Post. Beds are overturned to the north and dip south about 75 to 80 degrees.
62.7	0.3	Approximate position of an anticlinal axis.
63.1	0.4	A southwest-plunging synclinal ridge is at 3 o'clock; ridge is supported by the Oswego (Bald Eagle) sandstone.
63.5	0.4	Entering village of Milroy.
63.6	0.1	<u>BEAR LEFT</u> at stone house onto North Main Street to center of Milroy - route is not numbered.

Mileage

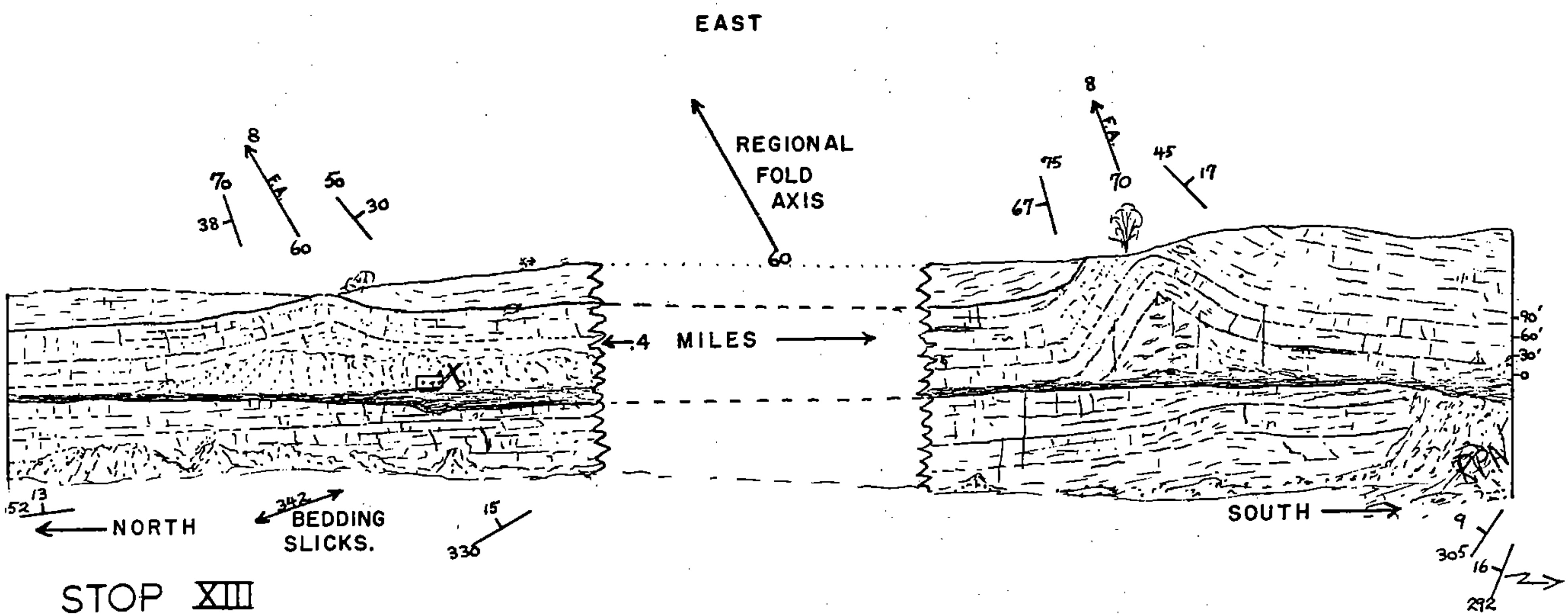
64.2	0.6	In the center of Milroy, BEAR LEFT on road to Siglerville.
64.5	0.3	Bridge over Laurel Run.
64.9	0.4	At "Y" intersection BEAR RIGHT.
65.4	0.5	Intersection; continue STRAIGHT AHEAD to Naginey. We are crossing an anticlinal axis in Bellefonte dolomite.
66.2	0.8	BEAR LEFT at entrance to quarry where sign announces: "Faylor Paving Materials Company, Naginey Plant." Quarry is owned by Bethlehem Limestone Company.
66.3	0.1	STOP XIII. Group leader - Dr. Richard P. Nickelsen, Bucknell University. Park at the top of small rise near operations offices to view structure in the Trenton-Black River limestones exposed in the Naginey Quarry. Follow group leader to observe broadly folded synclinal nose and anomalous development of two flanking and rootless anticlines.

General

This exposure, oriented approximately N-S, shows about 1/2 mile of structure section in a quarry of the Bethlehem Limestone Company across the noise of a N60° E plunging, second order, syncline within the Kishacoquillas Valley Anticlinorium. Important geologic features at this stop are illustrated in the sketch for Stop XIII (Figure 10); they are two rootless, third order anticlines which are developed at approximately the same stratigraphic horizons in the Black River and Trenton Limestones at the north and south ends of the exposure. Only the southern anticline will be studied.

Description of Outcrop

The quarry offers an unusual opportunity to observe the development of third order folds which are not the direct result of general shortening of section but rather develop due to increased axial crowding at higher stratigraphic levels



Quarry Exposure in Bethlehem Limestone Company quarry at Naginey, Pa.

Figure 10

in a major second order syncline. Features, present in the quarry, that are pertinent to the interpretation of these structures are:

1. decreasing fold amplitude downward in the section; (The fold near the south end of the quarry does not completely die out within the quarry but its amplitude diminishes rapidly downward within the exposed face. The fold of lesser amplitude at the north end of the quarry disappears completely before the quarry floor is reached.);

2. both folds have axes approximately paralleling the regional fold axis and thus are related to folding of first and second order folds;

3. bedding slickensides at a number of places on the large bedding surface making up the floor of the quarry trend 80° or 90° to regional and local fold axes (azimuth trend of slickensides is 342°), indicating that bedding plane slip is in a direction congruent with concentric folding of the limestones; and

4. limestones in the southern, third order, anticline have been bent with some fracturing and faulting in the upper part of the structure but in the lower part the beds have been thickened mechanically, with accompanying shattering and calcite veining. (There is little megascopic evidence of plastic deformation of limestones here or elsewhere in central Pennsylvania, for they behave as brittle, competent units.)

Summary

This stop was included in the trip to dramatically demonstrate third order folds that have developed as a secondary result of bending in the noise of a very broadly folded second order syncline. These structures are rootless, increase in amplitude upward, are probably restricted to the hinges of larger order anticlines and synclines, and are fundamentally different in origin from the folds of varying orders of magnitude that develop in different structural lithic units in response to mechanical and geometric characteristics of dominant members subjected to a general shortening of section. More important, in a broadly folded syncline such as this where the center of curvature is probably more than 10,000 feet above the quarry floor, they indicate insufficient bedding slip adjustment between beds to alleviate crowding in even the outer arc of fold curvature. Features such as these have lead me to question the efficiency of bedding plane slip in the concentric folding process. That differential bedding plane slip does occur is proven by slickensides oriented perpendicular to fold axes on the bedding plane floor of the quarry. Whether such bedding plane slip is generally sufficient in magnitude to allow the theoretical maximum of bedding plane adjustment to occur above and below the center of fold curvature in complete concentric folding (DeSitter, 1958, p. 283) of anticlines and synclines, is questionable.

Mileage

66.4	0.1	Rejoin paved highway at quarry entrance, TURN LEFT.
66.6	0.2	At 3 o'clock the business offices of the Bethlehem Limestone Company, Naginey Plant.
67.2	0.6	Intersection; TURN RIGHT over Honey Creek bridge toward Reedsville. Road parallels Jacks Mountain at 9 o'clock, with Tuscarora ridge on skyline and Oswego (Bald Eagle) sandstone forming the secondary ridge. Jacks Mountain is the southeast flank of Kishacoquillas Valley Anticlinorium.
67.9	0.7	Northwest-dipping Middle Ordovician limestone is exposed in road-cut at 9 o'clock.
68.2	0.3	Bridge over Honey Creek.
68.3	0.1	Southeast-dipping Middle Ordovician limestone can be seen in abandoned quarry at 10 o'clock.
69.4	1.1	Southeast-dipping Upper Trenton limestone at 3 o'clock.

Mileage

70.1	0.7	Several tight minor folds are exposed in southeast-dipping Upper Trenton limestone in road-cupts at 3 o'clock.
71.3	1.2	Entering the village of Reedsville.
71.8	0.5	At signal, TURN LEFT onto U.S.-322 (East). Route continues southeast on U.S.-322. At Mann Narrows the Kishacoquillas Creek cuts through Jacks Mountain. At the present time road construction exposes as excellent section of Silurian and Ordovician rocks.
72.1	0.3	Southeast-dipping Reedsville shale in Jacks Mountain. This is the type locality of the Reedsville shale.
72.2	0.1	Reedsville shale is in contact with Oswego (Bald Eagle) sandstone. Oswego is sandstone and conglomerate and approximately 600 feet thick.
72.3	0.1	Lost Run conglomerate member of the Oswego (Bald Eagle) sandstone is exposed here. Juniata Formation is 1500 to 1600 feet thick at this spot.
72.9	0.6	Bridge over Kishacoquillas Creek. Tuscarora sandstone forms a large ledge on mountain side above road at 9 o'clock; Tuscarora sandstone is about 400 feet thick here.
73.0	0.1	Entering the village of Yeagertown.
74.4	1.4	Entering the Borough of Burnham.
74.8	0.4	Abandoned Keyser limestone quarry may be seen at 10 o'clock in the distance.
76.2	1.4	Lewistown Bypass; BEAR RIGHT.
76.4	0.2	An abandoned Keyser limestone quarry is at 10 o'clock.
76.8	0.4	Devonian black shales are at 3 o'clock.
78.1	1.3	Approximate contact of Silurian Wills Creek shale and Bloomsburg Formation occurs here.

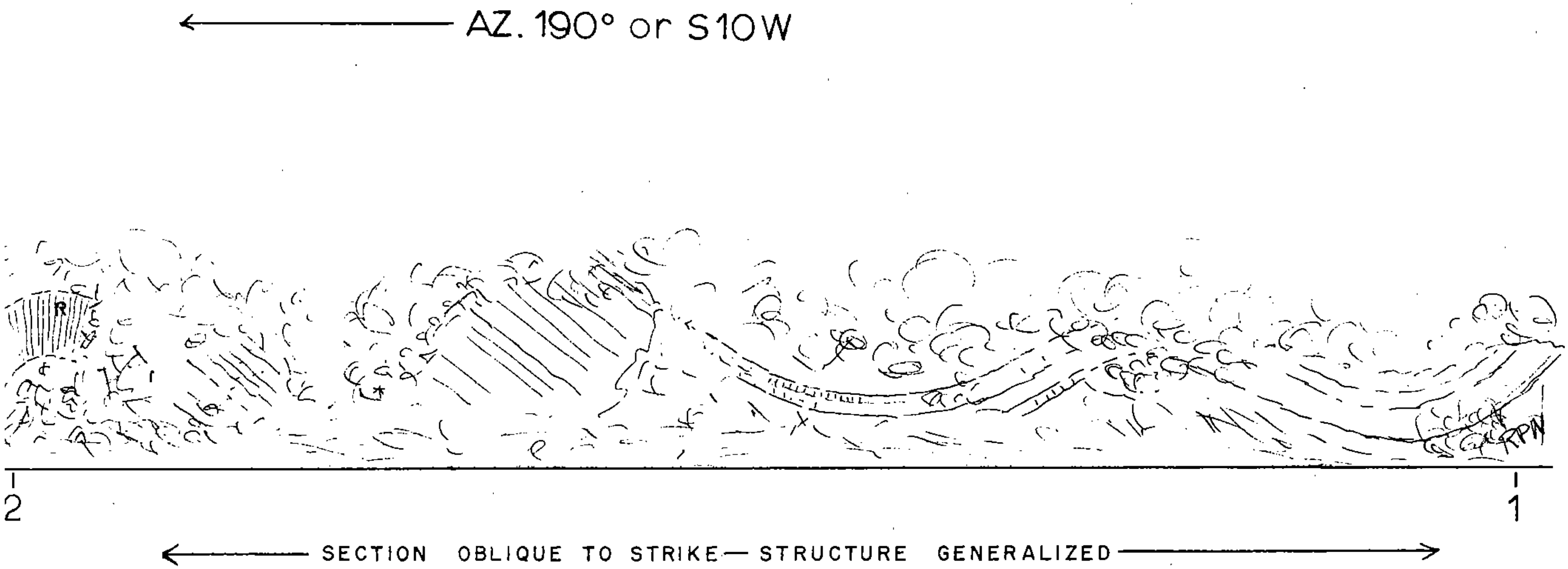
Mileage

78.4	0.3	Silurian Rose Hill shale is exposed in road-cuts on both sides; limestones of the overlying McKenzie Formation are present but not visible in this same cut.
78.7	0.3	Route passes over the southwest-plunging nose of Shade Mountain Anticline. In road-cuts at 9 o'clock are outcrops of Silurian Castanea sandstones and upper Tuscarora sandstone.
79.3	0.6	Castanea and Tuscarora sandstones on the southwest plunge of Shade Mountain Anticline occur at 9 o'clock. At 12 o'clock are near vertical cliffs of Tuscarora sandstone on the northwest flank of Blue Mountain Anticline. Excellent exposures of Tuscarora sandstones float may be seen in files of periglacial material.
79.7	0.4	Entering Lewistown Narrows, the valley of the Juniata River which is structurally a syncline, with the Rose Hill shale lying on top of the Tuscarora sandstone in the trough between Shade Mountain and Blue Mountain anticlines. Blue Mountain Anticline is at 3 o'clock and Shade Mountain Anticline is at 9 o'clock.
81.7	2.0	Contorted but essentially vertical upper Tuscarora outcrops at 9 o'clock.
82.0	0.3	Large periglacial block field of Tuscarora sandstone scree is at 9 o'clock.
83.6	1.6	Silurian Rose Hill shale can be seen at 9 o'clock.
84.1	0.5	Decreasing height of Blue Mountain anticlinal ridge at 3 o'clock indicates the northeast plunge.
85.7	1.6	Blocks of Tuscarora sandstone on the plunging nose of Blue Mountain Anticline.
86.4	0.7	Silurian Keefer sandstone can be seen above road level at 9 o'clock.
88.1	1.7	Crossing Lost Creek at village of Cuba Mills.

Mileage

88.6	0.5	Southeast-dipping Silurian Rose Hill shale outcrops at 9 o'clock behind the service station.
88.7	0.1	Blacklog Mountain Anticline is at 3 o'clock.
89.0	0.3	Rocks of the southeast-dipping Rochester-McKenzie Formations are at 9 o'clock.
89.1	0.1	Southeast-dipping Bloomsburg Formation can be seen in road-cuts at 9 o'clock; it is 367 feet thick here.
89.3	0.2	Contact of Silurian Bloomsburg Formation with Wills Creek shale occurs in road-cuts at 9 o'clock.
89.5	0.2	Entering the Borough of Mifflintown.
89.7	0.2	Junction of U.S.-322 (and 22) with Pa.-35 (South) at the traffic signal. TURN RIGHT and proceed on Pa.-35 (South).
89.8	0.1	Bridge over the Juniata River.
89.9	0.1	Entering Mifflin. Continue STRAIGHT AHEAD to dead-end at Penna. R.R. track.
90.1	0.2	At dead-end, TURN LEFT on Railroad Avenue and continue to Pennsylvania Railroad depot.
90.2	0.1	STOP XIV. Group leader - Dr. Richard P. Nickelsen, Bucknell University. Starting at the Pennsylvanian Railroad depot, follow group leader approximately 1/2 mile south along railroad tracks to view excellent exposures of third order structures in the Wills Creek Formation.

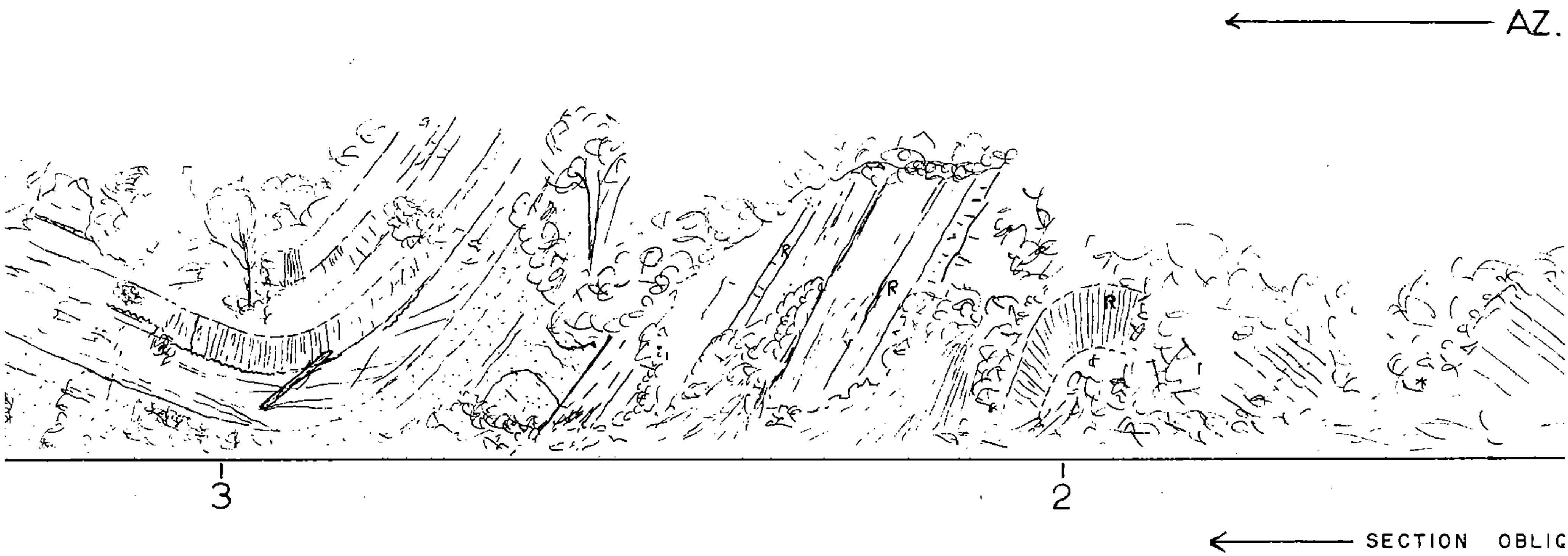
Maintain continued caution and BE ALERT FOR TRAINS.



STOP XIV

Folds along Railroad tracks and Juniata River south of Mifflin, Pa.

Figure II


AZ.
R
R
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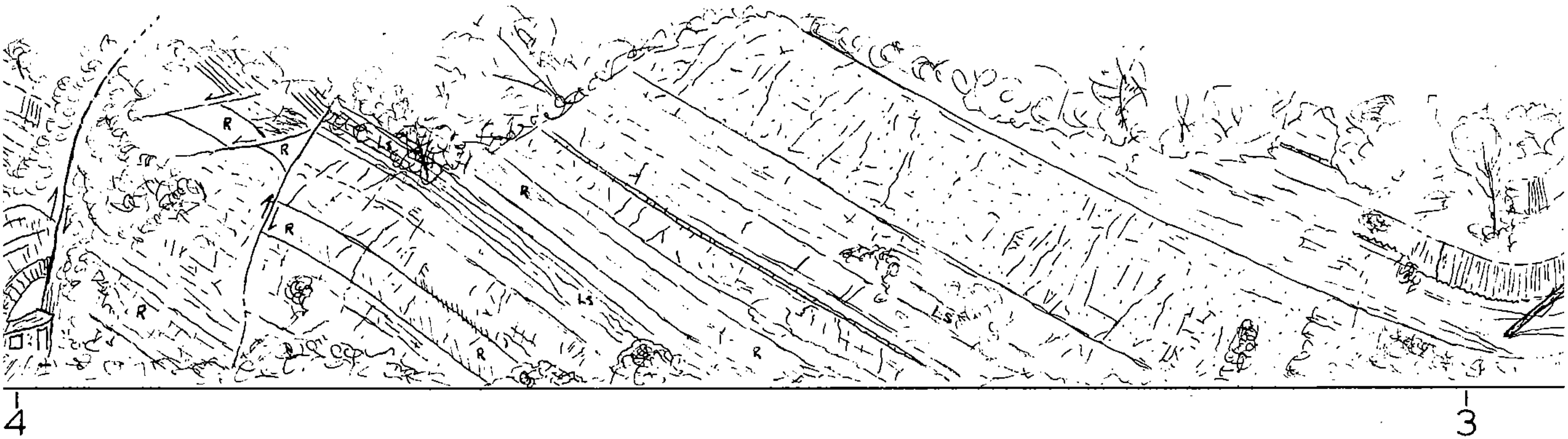
3
2
SECTION OBLIC


R
R
R
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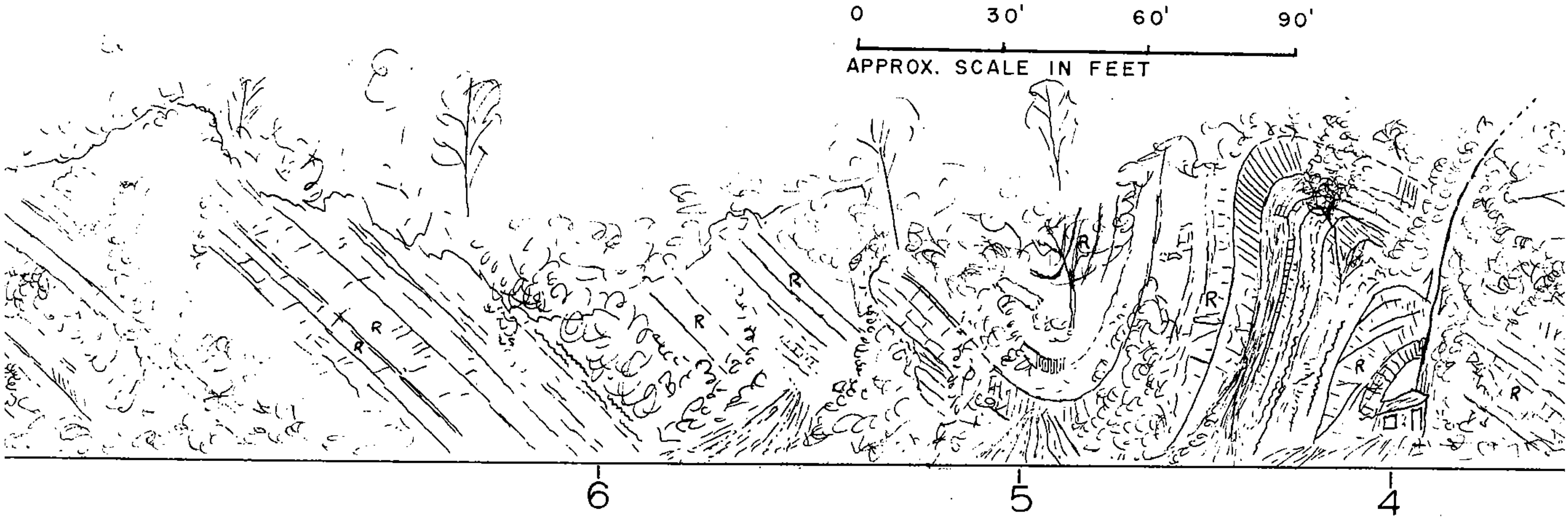
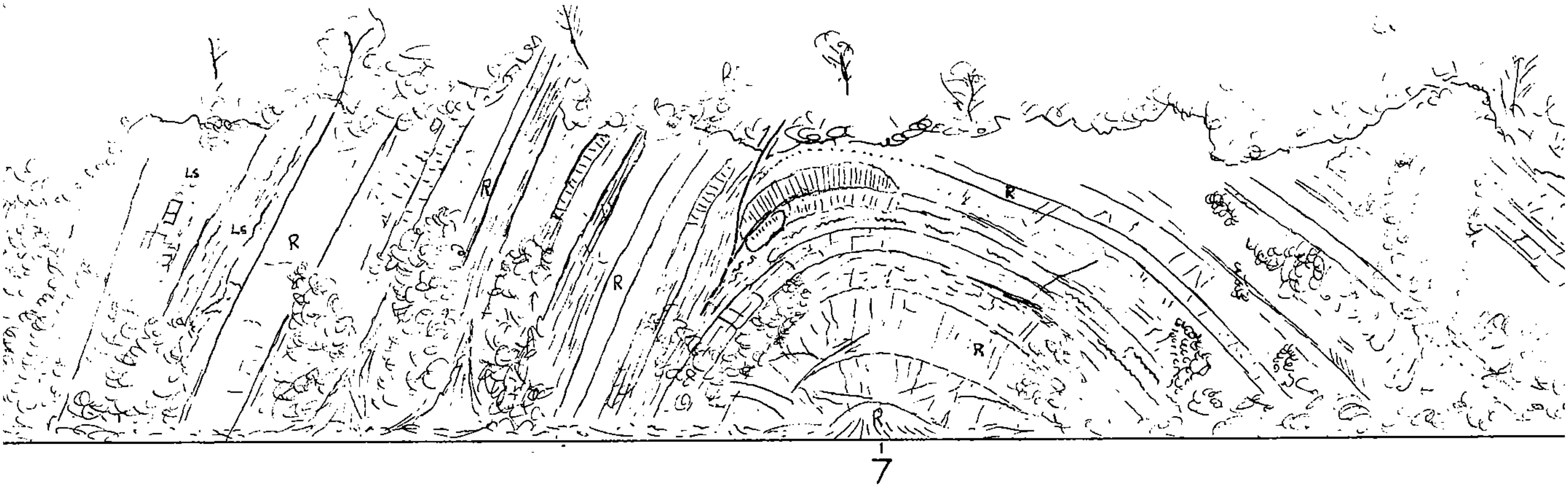
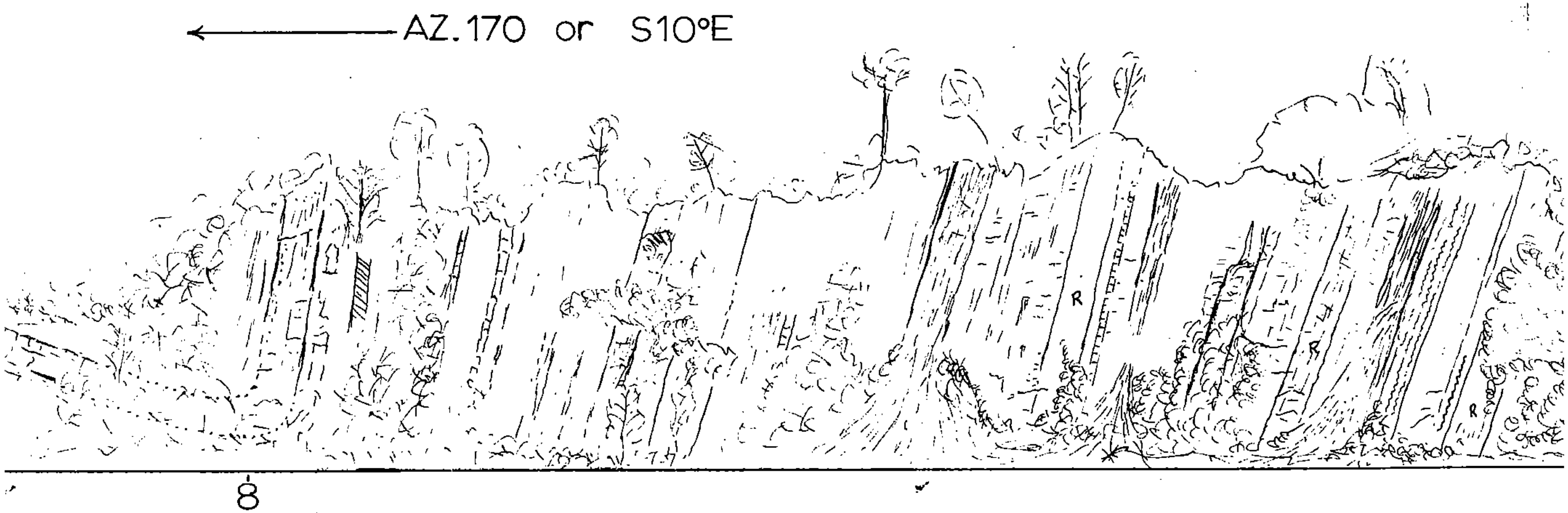
R
LS
R
LS
4
3


0
30'
60'
90'
APPROX. SCALE IN FEET
R
6
5
4


LS
LS
R
R
R
R
R
R
7



Folds along Railroad tracks and Juniata River south of Mifflin, Pa.

General

This exposure of several Third order anticlines and synclines in the Upper Silurian Wills Creek Formation is one of the best in central Pennsylvania for illustrating concentric folds and their mechanics of formation. These folds lie just east of the culmination of the Pennsylvania salient, within a bundle of Second order folds that plunge east into the Middle Anthracite field.

Folds in the section are all asymmetric to the southeast because of their position on a Second order fold. However, bedding wedges and an important upthrust within the section indicate over-riding toward the northwest.

The following descriptions of features to be seen have been keyed by numbers to the accompanying sketch of the exposure. (See Figure 11).

Essentially, the structure sections consist of a major Third order syncline at #3, separated, by a fault and anticline-syncline combination at 4 and 5, from a major Third order anticline at #7. The syncline at #8 is the last major fold exposed in the section.

Description of outcrop

(1) Start of section - structure generalized between (1) and (2) because poorly exposed and oblique to RR tracks and thus difficult to represent.

(2) Start detailed consideration of structure. Tightly compressed anticlinal axis in red mudstone with well-developed fanning fracture cleavage.

(3) Broadly folded synclinal axis, asymmetric to the south.

Note particularly a thick (30'), massive, sandy mudstone which is the most competent unit in the whole section and perhaps controls the wave length of folding (see discussion in Summary). Mudstone above log in the core of the fold shows excellent axial-plane fracture cleavage on the axis of the fold. Cleavage becomes less prominent and "fans" approximately perpendicular to bedding on limbs. In this bed, intra-bed deformation has taken place by flattening in fracture cleavage planes perpendicular to bedding. Perpendicular flowage of material along fracture cleavage has probably thickened bed.

Directly below cleaved bed is thin-bedded shaly limestone which has deformed by crinkling into minor folds (amplitude ± 1") in response to the same lateral stress (directed along bedding plane) which produced cleavage-flowage in overlying bed.

Beneath crinkled bed is another mudstone which has been slightly thickened in the trough of the fold by failure along intra-bed thrust faults with acute intersections directed along the bedding plane. Thus, three different processes contribute to the small-scale intra-bed continuous, or semi-continuous, deformation occurring in the trough of this fold:

a) fracture cleavage flowage was oriented perpendicular to bedding and was produced by a stress acting parallel to bedding;

b) symmetrical crinkling, or micro-folding, with axial planes perpendicular to bedding; produced by a stress acting along bedding plane; and

c) intra-bed, small-scale thrusting along planes acutely intersecting with bedding planes.

All of these processes lead to local small-scale thickening of the section and were perhaps initiated before complete lithification and before major folding.

(4) Tightly folded and complexly faulted anticline above small watchman's shack.

The steep upthrust rising above the shack is the largest fault exposed in the section and brings older parts of Wills Creek Formation to the north of the fault. I do not believe that any of the section exposed north of the fault is present in this section south of the fault, with the possible exception of some of the beds at the extreme southern end of the section. A small fault with same sense of displacement is well-exposed 30' north of the shack.

The anticline south of the shack at #4 is asymmetric to the south and shows fanning fracture cleavage, crinkled shaly limestone beds, and a prominent red-bed in the core of the fold is a bed which has been duplicated by a bedding thrust which turns and cuts acutely through the bed. This feature has been termed "wedging" by Cloos (1961). It is a less continuous mechanism of producing section thickening than the three intra-bed mechanisms described above.

(5) Syncline, asymmetric to the south.

Note the well-developed fracture cleavage parallel to the axial plane of fold in trough which decreases in importance and fans out on the limbs. Bedding planes to the upper right show bedding and strike joints intersecting to form "logs" elongated in fold axis.

(6) Crinkled fine-grained shaly limestone beds on the limb of the fold show that microfolds are not restricted to fold hinges but occur throughout the section in lithologies that are receptive.

(7) Major Third order anticline, faulted, thickened and asymmetric to the south.

South limb has ridden up and over the crest and north limb along a bedding fault which breaks through the crest of the anticline. This would appear to be the incipient phase of development of larger fault such as is exposed at (4). The well-cleaved bed in the upper part of the anticline is apparently doubled in thickness by "wedging" along a branch of this fault.

Fracture cleavage flowage and intra-bed faulting have both contributed to thickening of beds in the core of fold.

Beyond #7 nothing of significance is exposed that has not been seen already. The last fold hinge, a syncline, asymmetric to the south, is exposed at #8.

Summary

The form of folds more closely approximates a sine curve than a series of circular arcs. However, these folds have to be classified genetically as concentric, or flexure folds. The limbs of the folds are typically nearly planar and show few minor structures such as parasitic folds, boudins, etc. At this structural level in the section most complications such as minor folds, faults and wedges are encountered in anticlinal axes; the synclinal axes are typically uncomplicated. In the tight syncline at #5, upper, poorly exposed, parts of the section do seem to show minor complications. From these observations it is perhaps safe to conclude that we are standing at approximately the level of the centers of curvature of the anticlines and somewhat (50' or 100' ?) below the centers of curvature of the synclines. Presumably, at higher structural levels synclinal troughs become complicated due to crowding of material in the hinge of the folds by the bending process. Our best candidate for the dominant member establishing the wave length of Third order folding in this part of the section is the thick sandy mudstone at #3. However, using the relationship between thickness of the dominant member and fold wave-length established by Currie, et al, (1962, p. 666):

$\frac{\text{Wave length}}{\text{Thickness}} \sim 27$ we do not arrive at a wave length-thickness ratio anything like the magic number of 27. I am unsure of the exact reason for the discrepancy but it probably hinges upon one or more of the following:

a) the sandy mudstone at #3 is <u>not</u> the dominant member controlling fold wave length but the dominant member occurs in a higher, unexposed part of the section; alternatively the sandy mudstone is the competent member but more than the 30' measured behaves competently;

b) the fault at #4 is of such magnitude that it badly distorts wave length measurements;

c) wave length in the upper part of section (between synclines at 3 and 8, wave length is 1080') appears different from the wave length in lower part of section (wave length between anticlines at 4 and 7 is 360'); different parts of the section are thus controlled by different dominant members, folding is somewhat disharmonic, and no measurements of wave length should be attempted until structural lithic units are established.

Although the folds would appear to be concentric folds, no bedding plane slickensides perpendicular to fold axes have been found. Evidence of bedding plane slip is therefore lacking, but such slip should have occurred to allow material to slip out of anticlinal and synclinal hinges and elleviate the crowding which results in the lower part of anticlines and upper part of synclines. Alternatively, it is possible that fracture cleavage flowage, intra-bed faulting, small scale crinkling, wedging and doubling of beds and relatively major faulting originating in anticlines as at (4) and resulting in local thickening of the section in the hinge of folds, may have alleviated the axial crowding that must occur during the folding process. Even though direct evidence of bedding slip is lacking, I do not believe that the section shows sufficient adjustment by these other processes to remove the necessity of accepting some bedding plane slip.

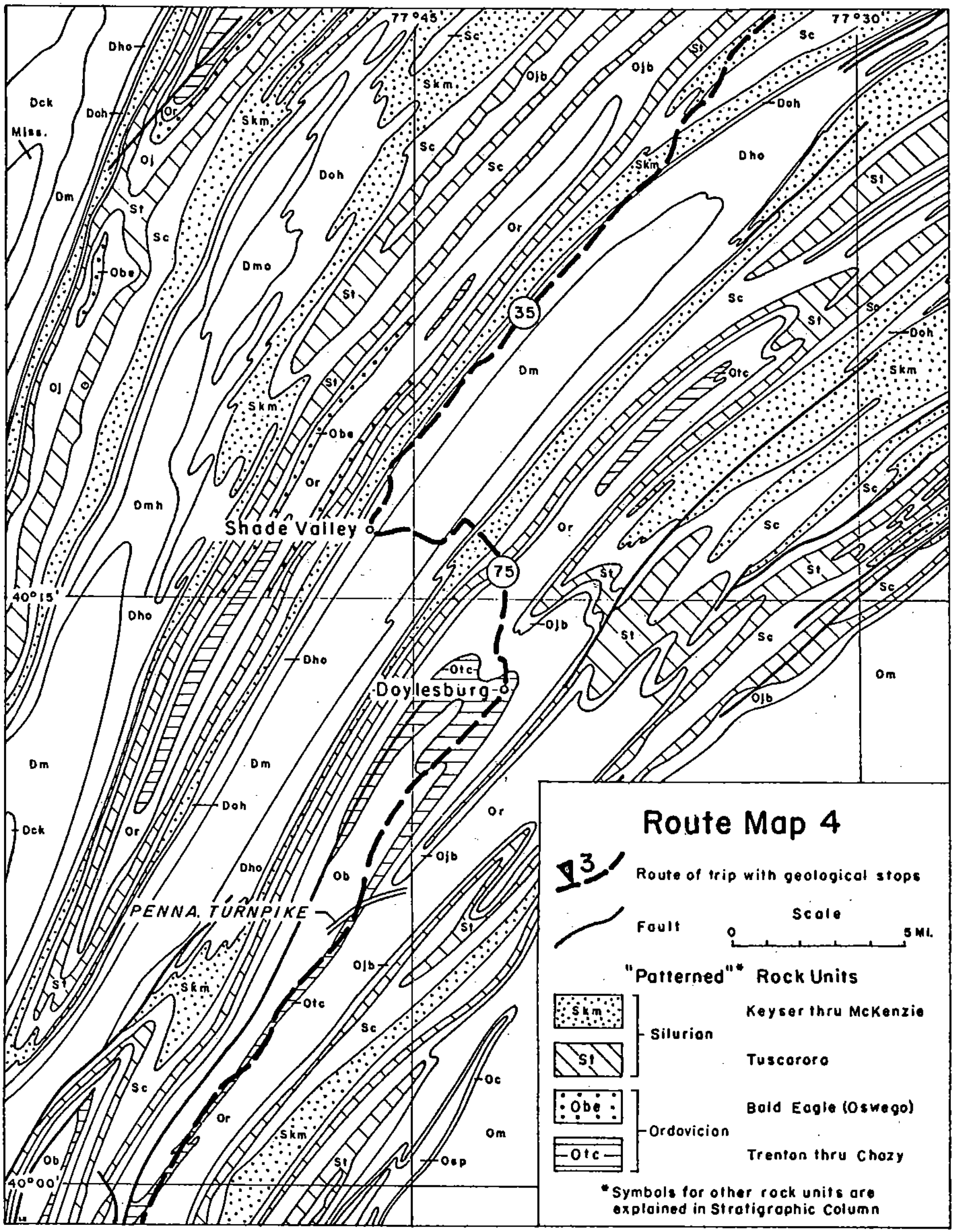
Certain thin-bedded shaly limestones are crinkled into minor folds throughout the section on fold hinges and limbs alike. These are not normal parasitic, or "drag" folds in that they are symmetrical with axial planes which are perpendicular to bedding. My present prejudice is that these minor folds, as well as some fracture cleavage and intra-bed faulting are developed early in the deformational history during a general NW-SE squeezing before the major folding starts. This squeezing and flattening may have occurred prior to lithification of all sediments and different sediments may have behaved differently - some by the plastic flow of water-sediment mixtures (Maxwell, 1962), others by crinkling of partically lithified sediment (most typical of limestones which might be expected to be lithified before other sediments in this section) and others by intra-bed faulting. Cloos (1961) has suggested that bedding slips and wedges may develop early and that wedging may initiate anticlines. Note that anticlines at (4) and (7) both show wedging. It is possible that "wedging" (small scale thrusting limited by bedding planes) occurs at the time of early squeezing and flattening or slightly later, and is responsible for initiating anticlines. If so, it is incorrect to infer that wedges are produced to alleviate crowding at fold hinges. The problem then is deciding whether: (1) Third order anticlines develop in the places that they do because wedging and flattening processes initially are concentrated there before folding; or whether: (2) wedging and flattening develop after folding has begun to alleviate crowding in anticlines where incomplete adjustment by bedding slip has occurred; or whether: (3) wedging and the various flattening processes are effective both early, before folding and as an agent for initiating folding, and later, as a mechanism for alleviating the crowding in fold hinges.

Mileage

Return to buses and proceed via Railroad Street to Pa.-35.

90.3	0.1	Junction with Pa.-35 (South) at "Stop" sign TURN RIGHT and proceed on Pa.-35 (South).
90.5	0.2	Bridge crosses Pennsylvania Railroad tracks.
90.7	0.2	In Silurian Tonoloway limestone.
90.9	0.2	In Silurian Wills Creek shale.
91.8	0.9	Bridge crosses Licking Creek. Route parallels strike in poor exposures of Silurian Tonoloway limestone and Wills Creek shale in synclinal valley.
92.9	1.1	Silurian Tonoloway limestone is exposed in road-cuts.
94.0	1.1	Blacklog Mountain Anticline - Tuscarora sandstone in core at 3 o'clock. Secondary flank ridge is supported by Silurian Keefer sandstone. Keefer sandstone also supports low ridge at 9 o'clock.

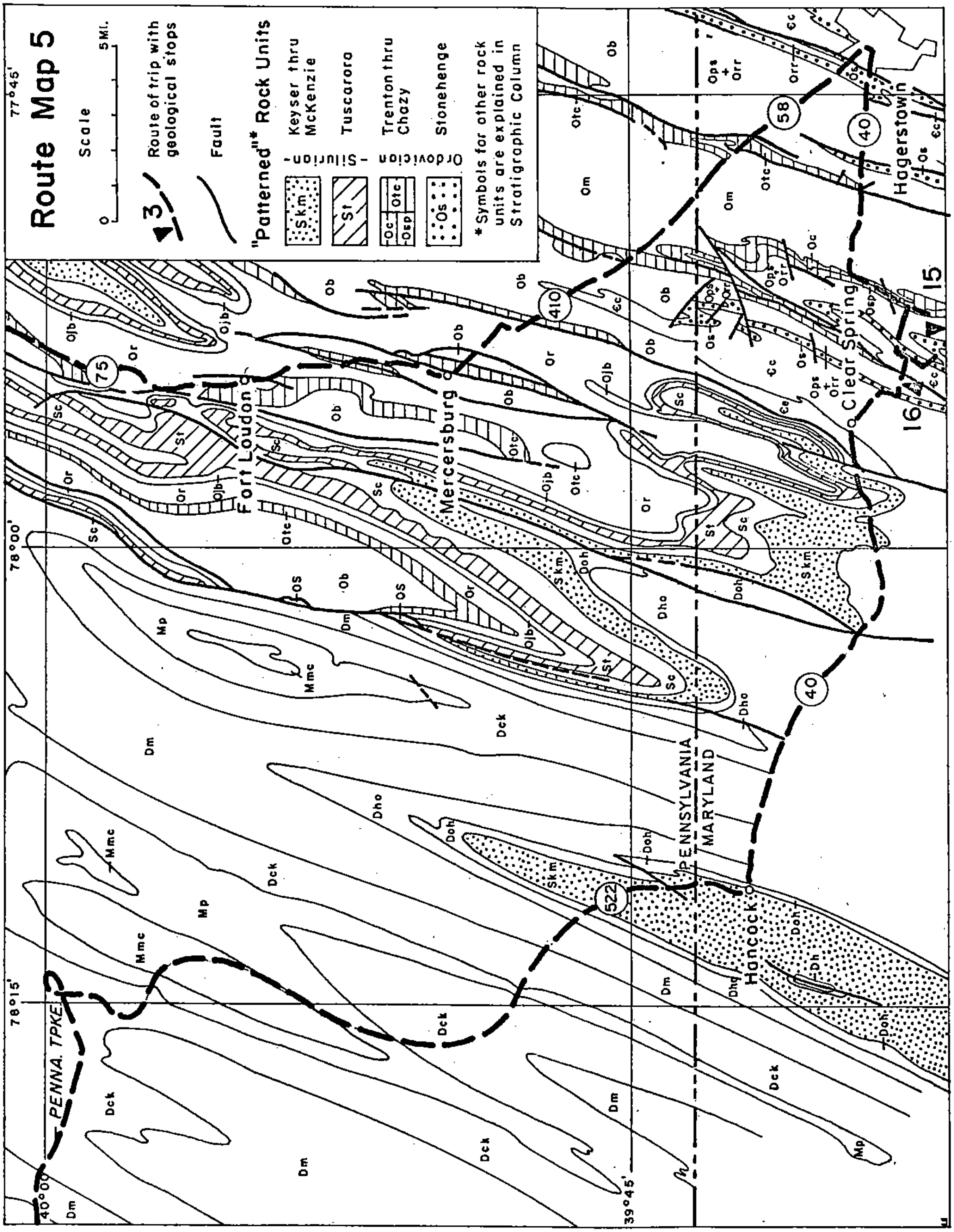
94.2	0.2	Tonoloway limestone can be seen in road-cut at 3 o'clock.
95.9	1.7	Entering village of Walnut. We continue in synclinal trough.
98.2	2.3	Tonoloway-Wills Creek contact; continue, traveling on Wills Creek.
98.7	0.5	Entering the village of Nook; we are in the Silurian McKenzie Formation.
100.5	1.8	Silurian Bloomsburg exposure in small road-cut at 3 o'clock.
101.5	1.0	Bloomsburg is exposed in road-cut at 3 o'clock. (Turn to Route Map 4).
103.1	1.6	At this road junction Keefer sandstone crop can be seen at 9 o'clock. Shade Mountain, the east flank of Blacklog Anticline is at 3 o'clock.
104.6	1.5	East-dipping Keefer sandstone is in road-cut at 3 o'clock.
105.3	0.7	Rocks of the Silurian Bloomsburg Formation can be seen along road. Lower Devonian Oriskany sandstone ridge is at 9 o'clock.
105.7	0.4	Entering the village of Reeds Gap. Shade Mountain at 3 o'clock is the east flank of Blacklog Anticline.
108.2	2.5	Crossing an Oriskany sandstone ridge.
108.7	0.5	Middle Devonian sandstone in the Hamilton Group (Middle Devonian) is at 9 o'clock in a low ridge. Road continues along an Oriskany-Helderberg ridge to Shade Valley.
110.8	2.1	Hamilton shale in road-cut at 3 o'clock.
111.6	0.8	Entering settlement of Peru Mills.
112.9	1.3	Hamilton shale in road-cut at 3 o'clock.
113.4	0.5	Entering settlement of Cross Keys.


Route Map 4
Route of trip with geological stops
Fault
Scale
0
5 MI.
"Patterned"* Rock Units
Skm
St
Silurian
Keyser thru McKenzie
Tuscarora
Obe
Otc
Ordovician
Bald Eagle (Oswego)
Trenton thru Chazy
*Symbols for other rock units are explained in Stratigraphic Column
Shade Valley
Doylesburg
PENNA. TURNPIKE
35
75
77°45'
77°30'
40°15'
40°00'
Miss.
Dck
Dho
Doh
Dm
Dmo
Dmh
Skm
Sc
St
Ojb
Oj
Or
Obe
Ob
Otc
Oc
Om
Osp

114.4	1.0	Route parallels contact between the Middle and Lower Devonian series.
116.2	1.8	Tuscarora Mountain appears briefly on the distant skyline at 11 o'clock. Sandstone of Hamilton Group supports the ridge at 9 o'clock.
116.5	0.3	Hamilton-Marcellus shales outcrop in cuts on both sides of highway.
116.7	0.2	Hamilton-Marcellus shales in road-cuts on both sides of route.
117.9	1.2	Oriskany sandstone is exposed in road-cuts.
118.7	0.8	Hamilton-Marcellus shales in road-cuts at 3 o'clock.
120.5	1.8	Entering the settlement of Shade Valley (Richvale). TURN LEFT toward Blairs Mills on an unmarked road following the drainage of Trough Spring Branch of Tuscarora Creek. Sands of the Hamilton Group (in the northwest flank of topographically high syncline) are exposed here.
122.1	1.6	Very gentle reversal at synclinal axis - in Upper Devonian marine shales. Road continues through similar stratigraphic section on the east flank of the syncline.
123.1	1.0	Intersection. TURN LEFT
123.5	0.4	Middle Devonian sandstone ridge at 9 o'clock.
124.2	0.7	Middle Devonian sandstone outcrop at 3 o'clock.
124.3	.01	Middle Devonian sandstone outcrop at 3 o'clock.
124.5	0.2	Entering Blairs Mills. TURN LEFT at Tuscarora State Bank on unmarked road.
124.6	0.1	TURN RIGHT. Tuscarora Mountain is at 12 o'clock.
125.8	0.2	Junction with Pa.-75 (South) at Spears Grove. Route (Pa.-75) follows the drainage of Narrows Branch of Tuscarora Creek through Concord Narrows of Tuscarora Mountain--Tuscarora Mountain is on the north-west flank of Tuscarora Anticline.

126.3	0.5	Tuscarora talus slope at 9 o'clock.
126.5	0.2	An exposure of nearly vertical Tuscarora sandstone.
126.8	0.3	Conocheague Mountain is at 9 O'clock. Reedsville shale is in the core of this anticlinal valley here.
127.3	0.5	Entering the village of Concord. Continue on Pa.-75 along strike in the Reedsville shale.
128.8	1.5	Knob Mountain is at 12 o'clock. Continuation of Tuscarora sandstone ridge describes a "fish-tail" pattern for the bifurcating north-plunging axes of Tuscarora Anticline.
129.6	0.8	Junction with Pa.-274; continue on Pa.-75 (South).
129.9	0.3	Village of Doylesburg; bypass and continue in Reedsville shale. Tuscarora Mountain is at 3 o'clock and Knob Mountain is at 9 o'clock; both are Tuscarora sandstone - supported ridges and represent the northwest and southeast flanks, respectively, of Tuscarora Anticline.
131.7	1.8	Abandoned Middle Ordovician limestone quarry at 3 o'clock.
132.1	0.4	Abandoned Middle Ordovician limestone quarry at 9 o'clock.
132.7	0.6	Middle Ordovician limestone exposed in road-cut at 3 o'clock.
133.1	0.4	Beekmantown dolomite exposed in road-cuts on both sides.
134.5	0.6	Entering the village of Dry Run; in the Beekmantown dolomite.
134.9	0.4	West-dipping Middle Ordovician limestone is being quarried in an active quarry (at 3 o'clock) of the New Enterprise Stone and Lime Company (Trenton and St. Paul limestones).
136.0	1.1	Beekmantown exposed in a road-cut at 3 o'clock.
136.5	0.5	Entering village of Spring Run; take bypass.
136.7	0.2	Beekmantown outcrops on both sides of road.

136.9	0.2	Junction of Pa.-75 with Pa.-433; continue on Pa.-75 (South) STRAIGHT AHEAD.
137.4	0.5	Beekmantown dolomite is in road-cuts at 3 o'clock; we are continuing in an anticlinal valley.
138.1	0.7	Beekmantown outcrops.
139.0	0.9	Underpass beneath Pennsylvania Turnpike.
139.3	0.3	Village of Willow Hill. Route parallels strike in southeast-dipping Middle Ordovician limestone and Lower Ordovician Beekmantown dolomite along the southeast flank of the Tuscarora Anticline. Tuscarora Mountain is at 3 o'clock and Kittatinny Mountain at 9 o'clock.
141.3	2.0	A turnpike entrance is at 3 o'clock. Route is over dolomites of the Beekmantown Group; this is our first encounter with the predominantly limestone facies in the Beekmantown. A low ridge at 9 o'clock marks the approximate contact of the Middle Ordovician limestone and the Reedsville shale.
143.4	2.1	Entering the village of Fannettsburg; in Reedsville shale.
144.5	1.1	A Reedsville shale quarry is at 9 o'clock.
144.8	0.3	An abandoned Middle Ordovician limestone quarry is at 3 o'clock; outcrops continue into field.
145.1	0.3	Middle Ordovician limestone (southeast-dipping) is in road-cuts on both sides of road.
147.1	2.0	Limy dolomites of the Beekmantown group are in road-cut at 3 o'clock.
148.1	1.0	Entering the village of Metal. Route continues, as it has since before the Turnpike underpass, along the West Branch of Conococheague Creek which has been flowing in the Reedsville outcrop belt.
148.8	0.7	Dolomite and dolomitic limestone of Beekmantown Group outcrop in road-cuts on both sides of highway.


Route Map 5
Scale
0
5 MI.
Route of trip with geological stops
Fault
"Patterned"* Rock Units
Silurian
Ordovician
Skm
Keyser thru McKenzie
St
Tuscarora
Oc Otc Osp
Trenton thru Chazy
Os
Stonehenge
* Symbols for other rock units are explained in Stratigraphic Column
77°45'
78°00'
78°15'
40°00'
39°45'
PENNA. TPKE.
Fort Loudon
Mercersburg
Clear Spring
Hagerstown
Hancock
PENNSYLVANIA
MARYLAND
75
410
58
40
522
15
16
Dm
Dck
Dho
Doh
Dh
Mp
Mmc
Skm
Sc
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150.2	1.4	Reedsville shale is in road-cut at 3 o'clock. (Turn to Route Map 5).
151.8	1.6	Reedsville shale is in cuts on both sides of road.
152.2	0.4	Cowans Gap State Park turnoff - to the right; continue on Pa.-75 (South) paralleling the strike in Reedsville shale.
153.4	1.2	Reedsville shale outcrops in road-cuts.
154.5	1.1	Bridge over Township Run.
155.8	1.3	Village of Fort Louden at 9 o'clock.
156.2	1.4	Intersection of Pa.-75 with U.S.-30; continue <u>STRAIGHT AHEAD</u> on Pa.-75. Rattlesnake Ridge of Cove Mountain is on the skyline at 3 o'clock. Very calcareous Reedsville shale can be found in quarry at 9 o'clock. We are entering the Great Valley of Pennsylvania (a physiographic province), which to the south becomes the Cumberland Valley of Maryland and eventually the historical Shenandoah Valley of Virginia. The southern terminations of Kittatinny, Little, North and Front Mountains are at 9 o'clock distant.
157.9	1.7	Reedsville shale in cuts on both sides of road.
159.3	1.4	Middle Ordovician limestone quarry on both sides of road. Chambersburg and St. Paul Group is exposed in a small fault block.
159.9	0.6	Crossing Buck Creek.
160.0	0.1	Beekmantown dolomite is in road-cut at 3 o'clock.
160.9	0.9	Beekmantown dolomite can be seen in road-cuts.
161.2	0.3	Junction of Pa.-75 with Pa.-416. <u>BEAR RIGHT</u> Route continues on Pa.-416 (South) over Beekmantown dolomite.
162.4	1.2	Junction of Pa.-416 with Pa.-16. <u>BEAR LEFT</u> onto Pa.-16. Entering the Borough of Mercersburg, the boyhood home of James Buchanan, 15th President of the United States.

163.0	0.6	BEAR LEFT and continue on Pa.-16.
163.4	0.4	Beekmantown dolomite is in road-cut at 3 o'clock.
164.0	0.6	Reedsville shale is in road-cut at 3 o'clock.
164.7	0.7	Bear Pond Mountains are in distance at 3 o'clock.
165.3	0.6	TURN RIGHT on Pa.-416 (South) and travel on Middle Ordovician limestones of the St. Paul Group. West Branch of Conococheague Creek is at 9 o'clock.
165.4	0.1	Approximage contact of Middle Ordovician with Lower Ordovician.
165.7	0.3	Reedsville shale is in road-cuts at 3 o'clock.
166.3	0.6	Reedsville shale - St. Paul limestone fault contact - east side is "up".
166.6	0.3	Crossing Licking Creek; in Beekmantown Group.
167.5	0.9	Beekmantown Group in road-cuts.
167.7	0.2	Upper Cambrian Conococheague Formation is in crest of Welsh Run - Edenville Anticline.
168.7	1.0	Excellent exposures and fairly complete section of the Rockdale Run Member of the Beekmantown Group can be seen along drainage of Welsh Run at 9 o'clock. Entering village of Welsh Run.
170.7	2.0	We are on Martinsburg-Reedsville shale which here "floors" the Massanutten Syncline.
171.9	1.2	Entering the village of Nova. Route continues in Martinsburg shale, paralleling a reach of a meander of the Conococheague Creek. The Conococheague Creek stays within the Martinsburg shale in the core of the Massanutten Syncline.
172.9	1.0	Maryland State Line. Route number changes to Maryland-58; still in Martinsburg shale. The Middle Ordovician subdivisions of Neuman and the Lower Ordovician subdivisions of Sando will be used beyond this point. (See correlations on Figure 2, Wagner paper, page 6.)

173.8	0.9	Bridge over Conococheague Creek. Good Martinsburg outcrop at 9 o'clock in ramp up river bank; dip is northwesterly (and steep) back into Massanutten Syncline.
174.8	1.0	Fault contact of Martinsburg shale with Chambersburg limestone - eastern (limestone) block is overthrust ot the west.
175.2	0.4	Entering Cearfoss; approximately at the contact of the Middle Ordovician Chambersburg limestone with the St. Paul limestone.
175.4	0.2	Fault contact; Middle Ordovician St. Paul limestone with Lower Ordovician Rockdale Run Member of the Beekmantown Group. Route continues in Rockdale Run Formation for next 3.3 miles.
178.1	2.7	Join 4-lane highway (Cearfoss Pike).
178.9	0.8	Hagerstown city limits. Approximate contact with Lower Ordovician Stonehenge limestone.
179.5	0.6	Fault contact; Upper Cambrian Conococheague Formation is in eastern (up-thrown) block.
180.0	0.5	Pass under railroad underpass. In Lower Ordovician Stonehenge limestone.
180.4	0.4	TURN RIGHT on North Potomac Street (one-way street) and proceed two blocks to Washington Street.
180.6	0.2	TURN LEFT and park at southeast entrance to Hotel Alexander (You will be sleeping on Stonehenge tonight.)

END OF SECOND DAY