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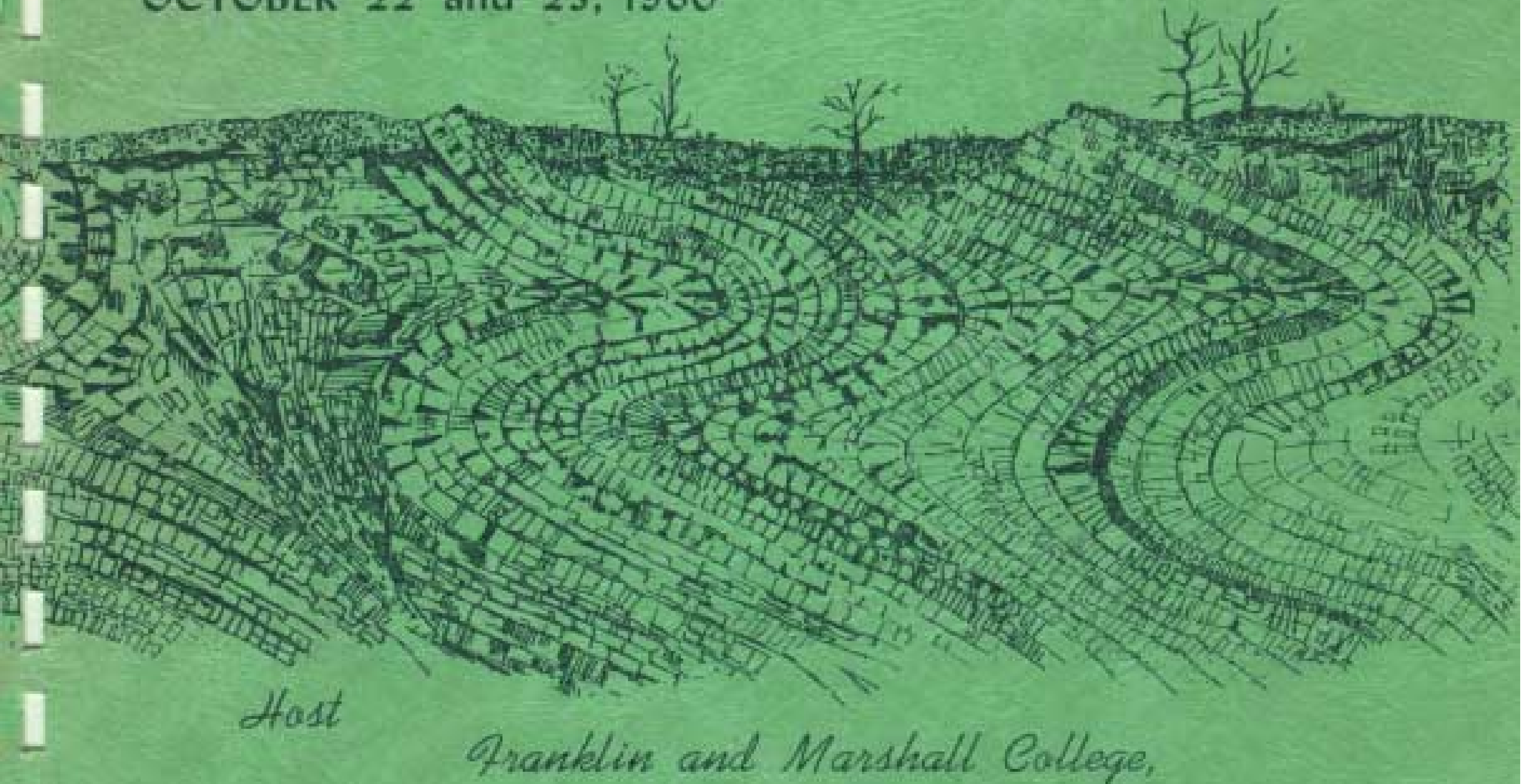
1960

GUIDEBOOK

25th. Annual Field Conference of Pennsylvania Geologists

LANCASTER, PA.

OCTOBER 22 and 23, 1960



Host

Franklin and Marshall College, Department of Geology, Lancaster, Pa.

SOME TECTONIC AND STRUCTURAL PROBLEMS OF THE APPALACHIAN PIEDMONT ALONG THE SUSQUEHANNA RIVER

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25TH FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

October 22-23, 1960

Hosts: Department of Geology
Franklin and Marshall College
Lancaster, Pennsylvania

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Wakefield, 1955
Quarryville, 1955
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Columbia East, 1955
Palmyra, CE 1943-47
Lebanon, 1955
Fredericksburg, 1955

1^{o} X 2^{o} Army Map Service sheets (Scale 1:250,000):

Baltimore
Harrisburg

GEOLOGIC MAPS AND QUADRANGLE REPORTS MOST PERTINENT TO FIELD CONFERENCE

Maryland Geological Survey Volume 13, 1937

McCalls Ferry - Quarryville Quadrangles: U. S. Geological Survey Bulletin 799, 1929

Geology of the Martic "Overthrust" and the Glenarm Series: Geol. Soc. America Special Paper 35, 1941

Lancaster Quadrangle: Penna. Geol. Survey Atlas 168, 1938

Middletown Quadrangle: U. S. Geol. Survey Bull. 840, 1933

Geology of the Lebanon Quadrangle: Penna. Geol. Survey Atlas 167C, 1958 source areas for the clastic sediments which comprise the Folded Appalachians. In effect, the new view brings "Appalachia" onto the continent as a former mobile belt which we can study at first hand rather than leaving it as a legendary land now buried at sea.

The evidence responsible for this changing opinion has come from many fields. Some of the basic pieces of data are:

(1) Radioactive age dating in the Piedmont has yielded ages spread over much of the Paleozoic. Rather than a great orogeny to close the Paleozoic, the bulk of the recrystallization seems to have taken place about 300-350 million years ago in early-middle Paleozoic time.

(2) Oceanography has revealed no continental crust out in the Atlantic Ocean as a former root for Appalachia.

(3) In the Southern Appalachians the asymmetry of the Piedmont belt begins to reverse in the easternmost portions, implying that the axis of deformation has been crossed.

(4) Sedimentary and stratigraphic studies indicate a source for the post middle-Ordovician sediments largely to the east. Rapid facies changes further suggest that this source area was not very far to the east.

(5) Hess postulates that a zone of "alpine" peridotites and serpentinites marks the axial regions of orogenic belts. The presence of the serpentines of this type up and down the Appalachian Inner Piedmont suggests this region is part of the axial zone.

(6) A generally similar location for the axial zone is suggested by Longwell's proposed bowing of the Appalachian core to form Triassic basins on either side of the uplifted region.

(7) Detailed structural studies have revealed some of the complexities of Piedmont deformation and some of the possible stratigraphic relationships within it.

The precise location of the axis of the intensely deformed core zone is a problem. Projection of tectonic trends along the Appalachians reveals that the Pennsylvania-Maryland region has less exposure of the Inner Piedmont than either New England or the Southern Appalachians because of more extensive cover by Coastal Plain sediments. The metamorphic isograds indicate a similar conclusion.

A very precise method of locating the axis of the Appalachian Geosyncline is by use of Hess's theory that two serpentine belts 120 miles apart outline the axial regions of alpine mountain systems. Two of these belts occur in the Appalachians <u>and</u>, in addition, many serpentines occur between these belts. The western of these belts for the Appalachians crosses the Susquehanna River at approximately the Pennsylvania-Maryland state line. If Hess's ideas are accepted the axis of the Appalachian Geosyncline should be about 60 miles (half of the 120 miles) to the southeast, beneath the Coastal Plain cover in the vicinity of Dover, Delaware. As noted above this method has precision in location but its accuracy is dependent on theory. With this reservation the location of the Piedmont axis in the vicinity of Dover may represent a fair working hypothesis.

In the Susquehanna River area there are a number of major tectonic units. These are illustrated on figure 1 and include from southeast to northwest: the schist belt of the Glenarm series including the Wissahickon schist; the Precambrian basement uplifts of Mine Ridge, the Honeybrook Upland and the

Welsh Mountains; the Lancaster Valley of Cambro-Ordovician limestones; Chickies anticline of Cambrian quartzite; the Triassic basins of the Furnace Hills with sill-like Triassic diabase intrusions; the structural low between the Reading prong of New England and the northern tip of the Blue Ridge; the Great Valley of Pennsylvania with Cambro-Ordovician limestone in its south half and Ordovician Martinsburg shale in its north half; and Kittatinny Ridge, the Silurian Tuscarora quartzite which forms the edge of the Ridge and Valley Province of the Appalachians.

These major tectonic units may be grouped into a number of sub-provinces or zones in the Piedmont following a general pattern of decreasing intensity of metamorphism from southeast to northwest. Exact boundaries between these zones are difficult or at places impossible to draw but the general sequence of zones along the Susquehanna River from SE to NW is:

(1) The zone of extensive granitization and/or intrusion. Along strike this zone shows extensive basement flowage and mantled gneiss domes in the Baltimore area.

(2) The schist belt (with the Hess-style line of serpentine bodies within it).

(3) Zone of tightly folded Cambro-Ordovician carbonates with steeply dipping axial planes in the Lancaster Valley. Some linear basement uplifts occur on strike with this zone.

(4) Zone of northwestward flowage and recumbent folding. There are some basement uplifts in this zone.

(5) A belt of Triassic cover across the middle of zone 4.

(6) The classic Ridge and Valley Province of the Folded Appalachians.

In considering these zones on the Susquehanna River cross section of the Piedmont, it would be well to keep in mind a number of structural generalizations in the area:

(1) The Susquehanna River Section of the Piedmont is unique in being on the major salient of the Appalachians. The tectonic "grain" in this area is nearly east-west in strike.

(2) The section is located at a pitch depression or structural low along the line of basement uplift extending from the Blue Ridge in the south, through the Reading Prong to New England.

(3) Southwestward, in the Baltimore Area, the basement is again exposed as a number of gneiss domes mantled with the metasediments of the Glenarm series.

(4) Radioactive age work indicates the basement to be about 1100 million years old with recrystallization of the micas in basement and in the nearby schists in the 300-350 million year range.

(5) Metamorphic rank decreases in general from south to north.

(6) A "schist" belt of the Glenarm series occurs near the Pennsylvania-Maryland state line. The northern contact of this belt of Glenarm rocks of uncertain age with rocks of known Cambro-Ordovician age to the north, is a line of considerable interest. The internal stratigraphy of both these areas is reasonably well known but their interrelationship is uncertain. This contact between the two areas is known as the MARTIC LINE and has been the center of lively debate for the last three decades.

(7) There is considerable thrusting and overturned folding in the area with most of the thrusts dipping to the south or southeast. This is also true of some of the nearby basement uplifts with thrusting along their northwest edges.

(8) A reversal of the dip of cleavage occurs in the vicinity of Lancaster. From Lancaster south to near the Tuquan anticline the cleavage dips north. Northward from Lancaster the cleavages and axial planes dip south, decreasing rapidly in dip to become horizontal. The recumbent folding

and horizontal transport persist northward as spectacular flow folding, large scale overturning and thrusting in parts of the Great Valley.

(9) A belt of alpine type peridotites and serpentinites parallel to the general Appalachian trend crosses the Susquehanna River near the Pennsylvania-Maryland state line.

(10) The general stratigraphy of the region within both the Glenarm series and the rocks of known Paleozoic age is, from basement upward, quartzites, carbonates, and pelitic sediments.

(11) Work on cross bedding by the Johns Hopkins group suggests that clastic sediments were being carried into the Appalachian Geosyncline from external sources to the west in Cambrian times and most likely through Middle Ordovician time. A reversal had occurred by the beginning of Silurian time and continued in general through the Paleozoic. With the reversal the clastic sediments were carried <u>out of</u> the center of the geosyncline. It is obvious that major new source areas for clastics were being created in the core region of the geosyncline and that these or similar sources persisted through most of the remainder of Paleozoic time.

(a) Major deformation in the core at about this time is also suggested by the 300-350 million year age dates from many of the Piedmont micas.

(b) One small, but visible, new source of sediments was the Bunker Hill volcanics interbedded with the Ordovician Martinsburg formation (Stop 12).

Thus the mid-Ordovician should be considered a critical time or a change in phase of the geosyncline marking the advent of major deformation in the core region. It also marks the change from dominant carbonate deposition to dominant clastic deposition.

(12) Three significant unconformities occur in the area:

(a) Precambrian: the basement surface of the Baltimore gneiss with either Cambrian quartzite or the Setters quartzite of the Glenarm series resting on it.

(b) Middle(?) Ordovician: the Ordovician Conestoga limestone rests on progressively older and older formations to the south and west, reaching as deep as the top of the Cambrian quartzites. Conglomerate breccias with blocks up to 8 feet across are associated with this unconformity.

(c) The base of the Triassic: bevels the regional fold pattern of the Paleozoic formations. The strata of the Triassic basins dip northward or northwestward at moderate angles into some border faults along their north edges. In some areas the Triassic redbed deposits contain locally derived coarse limestone block conglomerates.

The question of just where the Piedmont ends and the Folded Appalachians begin in this region may also be debated during the conference. Some of the possible solutions may be

(a) The older physiographic distinction of Piedmont versus Ridge and Valley with the Great Valley included in the latter.

(b) The true meaning of the word Piedmont as foot of the mountains suggesting that the boundary might be drawn at the foot of Kittatinny Ridge.

(c) Tectonic criteria based on the boundary of the intensely disturbed core of the Appalachians. Here the boundary of recumbent flowage, Cloos' Tectonite Front (if these are two different lines) or Hess' serpentine line might be utilized.

The Field Route

Many tectonic and structural problems are of special interest within a particular zone of the Piedmont; others carry over from zone to zone in a broader picture of Appalachian orogeny. This trip is designed to pass through the several zones, stopping at a few key outcrops to highlight some of the problems and to provide an open air forum for their discussion. The list of problems is by no means exhaustive nor necessarily an indication of relative importance. It simply is a compromise among the problems themselves, the quality of exposure along the general route, and of persons who have worked on these areas.

The twelve stops with their chief tectonic or structural problems are:

Location	Problem
First Day	
1. Port Deposit Granodiorite 2. Conowingo breccia	Igneous, near igneous rocks or granitization in the inner Piedmont
3. Cedar Hill Quarry	The serpentine problem
4. New Providence Railroad Cut	Thrusts(?) with later metamorphism
5. Pequea Silver Mine	Folded thrusts(?)
6. Williamson's Park, Lancaster	Higher order "S" surfaces
Second Day	
7. Oyster Point Quarry 8. Chickies Rock	Cleavage development and the deformation of quartzite
9. Rheems Quarry	Flow mechanisms in limestones
10. Conoy Creek Triassic Conglomerate	Triassic sediments and their basins of deposition
11. Annville Quarry	Nappe structures in the Great Valley
12. Bunker Hills Volcanics	Ordovician vulcanism and the change in phase of the Appalachian Geosyncline

Some of these problems and areas have had years of detailed field work on them; others have been undertaken only recently and are of interest because of the possible application of some theory. Thus this 25th Field Conference and this Guidebook represent a type of progress report and a reflection of some of the present climate of opinion on the problems rather than the final word on any of them.

Because of the wide range in areas and problems, a number of different workers have contributed to the Guidebook. Some of the contributions are in the form of short essays; others are in the form of an expanded lecture outline of a type that might be given on the outcrop itself.

It is hoped that this trip will further stimulate some thinking and discussion of the tectonic processes within the Piedmont, how these processes vary from zone to zone or are superimposed within a single zone, and how all these processes fit into the total picture of Appalachian orogeny.

Acknowledgments

The Pennsylvania Geological Survey has provided much of the encouragement for this trip; it aided in the printing of the Guidebook; and its members have contributed to the scientific material in it. Much of the early part of the trip stems from the wealth of material collected over the years by people associated with Johns Hopkins University. To the members of these two main groups, to a number of individuals as listed under their articles, and to our own college, the Department of Geology at Franklin and Marshall is grateful for assistance in the preparation of this conference and Guidebook.

Road Log - First Day

Assemble 8:30 A.M. at Port Deposit Quarry --
One-half mile north of the town of Port Deposit, Maryland, on U. S. Route 222.

STOP 1. PORT DEPOSIT

0.0 Leave Port Deposit Quarry, turn north (right) along the Susquehanna River.

3.4 Cross Conowingo Creek.

3.6 High Tension Power lines cross road. Turn left onto dirt road parallel to the lines. Park car and follow the lines out to the Susquehanna River. The outcrops of the Conowingo Breccia are on the shoreline just under the power lines.

STOP 2. CONOWINGO BRECCIA

3.6 Leave Conowingo Breccia and continue north along the River.

4.3 Junction with U. S. Route 1 and 222 at the east end of Conowingo Dam. Turn right and follow Route 222.

5.3 Turn left with Route 222 at Conowingo Inn.

8.5 Turn right at Crown Gas Station toward Cedar Hill Quarry.

9.0 Bear left at triangle.

9.5 Turn left at Cedar Hill Quarry sign.

10.2 Pequea Creek on the right.

10.6 Cedar Hill Quarry.

STOP 3. CEDAR HILL QUARRY

10.6 Leave Cedar Hill Quarry, continue on through quarry area under the conveyor belts turning left to climb out of quarry.

11.1 Bear left with main road.

11.2 Typical "pine barrens", a vegetation characteristically developed in serpentine in this region.

12.3 Turn right on Route 222 at the Pennsylvania-Maryland state line. FOLLOW ROUTE 222 for 13 miles INTO QUARRYVILLE.

Road Log - First Day
(Continued)

Crossed Peach Bottom Syncl.? Where are slate quarries?

15.3 Conowingo Creek.

16.9 Bear right with Route 222.

19.4 On left is the birthplace of Robert Fulton, inventor of the steamboat.

25.3 Enter Quarryville and cross the Martic Front where the Wissahickon schist of unknown age rests on the Ordovician Conestoga limestone to the north. Visible to the northeast is the plunging nose of the Mine Ridge Anticline, a basement uplift involving Baltimore gneiss.

Lunch stop in Quarryville.

Continue northward on Route 222 through Quarryville.

26.7 Bear right with Route 222 at traffic light.

27.3 Pennsylvania Railroad underpass.

27.7 On the left just beyond the floodplain are tailings ponds from old residual limonite workings to the west. The ready washed clay is now being used as a natural tile mix.

28.0 Ridge ahead is Antietam schist or quartzite which parallels the Martic Front for 10 miles to the west and merges with the Front 2 miles to the south.

28.4 Road cut through the above Antietam Ridge.

28.9 Cross Creek.

29.6 Turn left just beyond Amoco Gas Station.

29.8 Turn right just beyond Gulf Gas Station in New Providence.

29.9 Railroad underpass.

30.0 Bear left at "Y" fork.

30.3 Climb hill onto the Martic Front.

30.6 <u>STOP 4. NEW PROVIDENCE RAILROAD CUT</u>
The most interesting parts of the cut are north (right) of the overpass. It is easiest to get down into the cut by following along its edge on the east (near) side. Beware of trains!

Road Log - First Day
(Continued)

30.6 Leave Stop #4, continue in the same direction.

31.3 Straight through crossroads.

31.8 Right turn at "T" road.

32.3 Railroad overpass, exposures of Wissahickon schist.

32.5 Left turn at crossroads

For a number of miles the route follows a valley just south of the Martic Contact which is just over the hill to the north (right). This valley discussed in the notes above was interpreted by Knopf and Jonas as a fenster of Conestoga limestone showing through the "Martic Thrust". An alternative explanation is a calcareous unit in the Wissahickon schist.

32.9 Bear left at intersection.

33.4 Stop sign on Route 72 at Smithville. Turn left.

33.5 IMMEDIATELY TAKE FIRST RIGHT.

33.6 Railroad underpass.

34.5 Bear right at intersection.

34.6 Railroad overpass, bear left on other side.

35.2 Bear left past stop sign to follow ridge line.

35.6 Crest of ridge. This ridge is still Wissahickon schist but the Martic Contact is at the foot of it (ahead and to the right). View toward the right is across repeated imbrications of the Conestoga, Vintage and Antietam formations.

35.9 The Martic Line.

36.3 Road cuts in the Antietam schist. This is the same ridge of Antietam seen at mile 28.4. Note the general similarity to the Wissahickon schist.

36.7 Marticville, turn right at stop sign.

37.7 Cross Pequea Creek and immediately turn left on side road.

38.1 Ninety degree left turn, descend into the valley bottom.

Road Log - First Day
(Continued)

38.3 Silver Mines Run. Park, ask entry permission at farmhouse. Area of interest is 200 yards upstream from here.

STOP 5. PEQUEA SILVER MINES

38.3 Leave Silver Mines Run.

38.6 Bear right at "Y" road.

39.3 Straight through crossroads.

39.8 Road junctions. Continue straight ahead and slightly to the right onto main highway 324.

40.4 Straight through.

41.4 Turn right at crossroads by brick house.

41.7 "T" road, turn right, THEN IMMEDIATELY TURN LEFT (toward Willow Street).

42.9 Straight through crossroads at stop sign.

43.4 Traffic light at Mylins Corners. Continue straight through.

43.7 Left turn onto side road (Eshelman Mill Road).

44.0 Straight through.

44.1 Straight through.

44.3 Martin Mylins Gunshop (the little stone building). Here the earliest known Pennsylvania or "Kentucky long" rifle was made prior to 1745.

45.2 Sharp left turn. Good view of the Lancaster erosion surface at about 380 feet elevation. The meanders of the Conestoga River are entrenched into this surface to a depth of 120-140 feet.

45.6 Cross bridge over Conestoga River and bear left.

46.0 Straight through.

46.1 Straight through.

46.6 "T" road with entrance to Williamsons Park to left. Turn sharply left through the gates of the Park.

46.7 "T" lane in Park. The outcrops of interest are in the 150 feet to the right (north).

STOP 6. WILLIAMSONS PARK

46.7 Turn right on park lane and continue out through other gate of park, to the main highway 100 feet away. Left turn across bridge onto South Duke Street in Lancaster. Follow Duke Street into town.

48.3 Five way junction at traffic light. Turn left on Farnum Street for two blocks, then turn right on Queen Street. Follow Queen Street for two blocks to the monument in Penn Square, Lancaster. Continue straight through the square for two blocks. Hotel Brunswick is on the corner at the right.

Road Log - Second Day

Assemble 8:00 A.M. at the Main Entrance of Franklin and Marshall College, facing south. A map of Lancaster City is included in the Guidebook to assist in finding the college. (See Figure 11.)

0.0 Leave Franklin and Marshall College heading south on College Avenue.

0.4 Turn right on Marietta Avenue (just beyond St. Joseph's Hospital). Continue west on Marietta Avenue toward Rohrerstown and Oyster Point. Bedrock is Conestoga limestone.

1.0 Wheatland, home of President James Buchanan on left.

1.8 Cross Little Conestoga Creek.

2.8 Center of Rohrerstown; continue west; contact with Ledger dolomite.

3.1 DANGER!! High, narrow railroad bridge; contact with Kinzers shale.

3.3 On right (north) is the eastward plunging nose of the Chickies Ridge anticline. Here the Cambrian quartzites disappear beneath the younger Cambrian limestone formations.

4.3 Begin climb onto Chickies Ridge.

5.5 <u>STOP 7. OYSTER POINT QUARRY</u>

Continue west from Oyster Point; quartzite ridge on left (south); limestone and dolomite valley on right (north) underlain by Vintage and Ledger.

11.3 Turn left (south) at white barn.

11.6 Continue straight; climb onto Chickies Ridge; Susquehanna River is visible one-half mile to the west.

12.0 Continue onto main road bearing to the right (downhill).

12.3 STOP SIGN. Turn right onto Columbia-Marietta Pike. The huge new Chickies road cut, 175 feet deep through the ridge is located immediately to the left but will not be visited on the trip because of time and space limitations. The south end of the cut shows a huge overturned fold in quartzite, with break thrusting of less competent units on its overturned limb. The north end of the cut is a syncline adjacent to the overturned fold. It contains Harpers phyllite in the center and Chickies quartzite in the structurally lower northern parts. These relatively gently dipping quartzites at the north end of the cut are part of the same structure which can be seen at Chickies Rock (Stop 8).

12.6 STOP 8. CHICKIES ROCK
Park at Chickies Creek and walk left (west) along the lower slope of Chickies Ridge to the railroad cut (approximately 150 yards). Head north from Chickies Rock toward Marietta.

13.4 Stop Sign; Marietta; continue on and to the left.

14.3 Turn right on Route 141 on North New Haven Street; continue north on Route 141 toward Mt. Joy; bedrock is Vintage dolomite for next one-half mile, followed by Ledger dolomite and Conococheague limestone.

15.2 Turn left onto road toward Rheems; to left and rear (south) is Chickies Ridge and the gap of the Susquehanna River.

16.0 Intersection; continue straight.

17.8 Continue straight.

17.9 Continue straight.

19.3 T-intersection; turn left.

19.5 Intersection; continue straight.

20.0 Stop Sign; turn left (Rheems).

20.7 Turn left into Heisey Brothers quarry just before railroad underpass.

21.0 STOP 9. RHEEMS QUARRY
Leave quarry. Turn left. Do not go through underpass!

21.5 Hill at right is underlain by Triassic (New Oxford formation).

21.8 Turn right; go up over hill.

Road Log - Second Day
(Continued)

22.0 Straight through to sharp left turn at red barn.

22.3 Bear left on Route 340.

22.7 Turn right along crest of hill; route is on the Triassic border with the Ordovician limestones in the valleys immediately to the south and Chickies Ridge visible 5 miles to the south.

23.5 Turn left at triangle of T-intersection.

24.0 "Dog-leg" left at white barn.

24.1 "Dog-leg" right.

24.3 Intersection; continue straight.

24.7 Triassic diabase dike in woods; part of NNE trending dike system.

24.8 Sharp right turn.

25.1 STOP 10. CONOY CREEK - Triassic Conglomerates
Leave Conoy Creek and proceed north; next one-quarter mile shows road cuts of quartz pebble Triassic conglomerates.

25.4 Intersection; continue straight.

25.8 Stop sign; turn right on main Elizabethtown-Bainbridge road, Route 241.

28.1 Elizabethtown; continue straight through railroad underpass, do not turn left on route 241.

28.2 Railroad underpass on Bainbridge Street.

28.5 Traffic signal; turn left on U.S. Route 230.

28.7 Square in Elizabethtown; continue straight (west).

28.8 Turn right on Routes 241 and 340.

28.9 Turn left on Routes 241 and 340; outside Elizabethtown route continues in the Triassic New Oxford formation.

29.7 Bear right on Route 241 (Route 340 continues straight).

31.4 Route 241 turns left; Triassic diabase boulders along road.

Road Log - Second Day
(Continued)

32.3 Descend from diabase ridge; enter Gettysburg formation (Triassic) shales and sandstones.

33.7 Enter Lebanon County.

34.6 Underpass below Pennsylvania Turnpike.

35.3 Entering Lawn.

36.1 Cross railroad tracks.

36.9 Junction Penna. Route 341; continue on Route 241.

37.6 Stop Sign; junction Penna. 117; Colebrook; turn left (road to right to Mt. Gretna).

38.1 Bear right on Route 241; Route 117 turns left.

40.5 Descend from Triassic rocks to valley underlain by the Cambrian Conococheague formation (Buffalo Springs member); route parallels contact of Triassic (on right) with Cambrian (on left) for next four tenth mile.

40.9 DANGER! Sharp left turn.

41.4 Contact with Snitz Creek member of Conococheague formation at Bachman Run.

41.7 Contact with Schaefferstown member of Conococheague formation.

41.9 Contact with Millbach member of Conococheague formation.

42.0 Intersection U. S. Route 322; turn right (east).

42.2 Intersection Penna. Route 934; turn left (north).

42.3 Contact with Richland member of Conococheague formation; contact is irregular and a nose of Millbach recrosses road in next one-half mile.

43.4 Contact with Beekmantown group limestones.

45.3 Annville-Cleona High School.

45.8 Traffic signal; intersection Route 422; turn right (east).

46.1 Intersection with Bachman road; turn right (south) next to small stone building.

Road Log - Second Day
(Continued)

46.3 STOP 11. ANNVILLE QUARRY
Turn around in circle in front of quarry and head back toward Annville.

46.5 Intersection 422. DANGER! Turn left (west) WITH CAUTION!

46.8 Traffic light; intersection Penna. Route 934; turn right (north) at gas station; continue past Lebanon Valley College on right (east).

47.0 Railroad overpass; Hershey limestone visible to left (west) in railroad cut; contact with Martinsburg shale 0.2 mile beyond railroad.

47.4 Turn right (east) just beyond cemetery; note outcrop of Martinsburg shale at intersection; route continues in Martinsburg shale and associated beds for rest of trip.

48.3 Stop Sign; continue straight.

49.5 DANGER! S-curve and bridge.

50.4 Cross road; continue straight.

52.1 Stop Sign; junction Route 72; turn left (north) WITH CAUTION!

52.5 View straight ahead (north) toward Swatara Gap in Kittatinny Mountain

53.5 Intersection old Route 22 (no route markers); turn right (east) at gas station.

53.9 Cross railroad track.

54.0 Cross Swatara Creek.

54.5 Intersection; South Lancaster Street; turn right (south) at hotel.

54.8 Leave Jonestown.

54.9 Cross Little Swatara Creek.

55.0 Intersection (gravel road to right toward quarry). (Road to left toward volcanic rich sediments.) Route passes through Bunker Hills region of volcanics and intrusives.
TRIP ROUTE CONTINUES STRAIGHT THROUGH INTERSECTION.

Road Log - Second Day
(Continued)

56.0 Sharp left turn; park cars along road for Stop 12; please pull off roadway as far as possible and do <u>not</u> block driveways and side roads.

56.1 <u>STOP 12. BUNKER HILLS VOLCANICS</u> - Railroad cut, 10 yards west of road. This is the last stop of the field conference. All cars will continue on this road for one-half mile to intersection Route 72. Right (north) turn on Route 72 for two and one-half miles to U.S. Route 22; Harrisburg 23 miles west; Hamburg 30 miles east. Left (south) turn on Route 72 for Lebanon, 12 miles to Pennsylvania turnpike, and 28 miles to Lancaster.

56.6 Intersection Route 72; right (north) and left (south).

***** END ROAD LOG *****

STRATIGRAPHIC SUMMARY

TRIASSIC	Gettysburg fm New Oxford fm (= Stockton fm)
ORDOVICIAN	
Upper	Conestoga ls = ? Martinsburg fm = ? Cocalico sh
Middle	Hershey ls Myerstown ls Annville ls
Lower	Beekmantown gp Ontelaunee fm Epler fm Rickenbach fm Stonehenge fm
CAMBRIAN	
Upper	Conococheague ls Richland mbr Millbach mbr Schaefferstown mbr Snitz Creek mbr Buffalo Springs mbr
Middle	Elbrook ls
Lower	Ledger dolomite Kinzers fm Vintage dolomite Antietam quartzite Harpers phyllite Chickies quartzite Hellam cgl
ROCKS OF QUESTIONABLE AGE (Probably Lower Paleozoic)	
	Glenarm Series Peach Bottom slate Cardiff cgl Peters Creek schist Wissahickon fm Cockeysville marble Setters fm
PRECAMBRIAN	Crystalline basement complex; includes Baltimore gneiss, Byrum gneiss, Pickering gneiss, Pochuck gneiss, and others.

PIEDMONT STRATIGRAPHY NEAR THE SUSQUEHANNA RIVER

Marvin E. Kauffman
Franklin and Marshall College

TRIASSIC

Upper Triassic

Gettysburg formation

Shale member - soft red shale with interbedded coarse red sandstone and conglomerate tongues which become the Robeson conglomerate in Chester County.

Elizabeth Furnace conglomerate member - basal pebbly sandstone and conglomerate up to 2500 feet thick.

New Oxford formation (= Stockton formation of eastern areas)

Arkoses, ranging from very coarse to fine-grained, with some quartz pebble conglomerates, minor amounts of shale, siltstone, and some impure nodular limestone and limestone conglomerates.

ORDOVICIAN

Upper Ordovocian

Conestoga limestone (exact age uncertain, possibly equivalent in part to Martinsburg-Cocalico)

Blue limestone, closely folded, thin-bedded, argillaceous, with dark graphitic shale or slate and coarse conglomerate and breccia of limestone fragments in dark argillaceous and calcareous matrix (more than 1000 feet thick). Contains Strophomena stosei. Rests unconformably on formations as young as Beekmantown and as old as Antietam.

Martinsburg formation

Gray to black shale, argillaceous sandstone, with purple and red shale near base; contains volcanic contributions in Jonestown area; Cocalico shale of Lancaster County is probably equivalent to the Martinsburg; it also contains bluish-black and dark gray fissile shale with some purple, green, and red shale near the base, possibly derived from volcanic ash (?). Contains some graptolites.

Middle Ordovician

Hershey limestone

Dark gray-black, thin bedded limestone; weathers to brownish-gray surface and shows well developed cleavage (200-350 feet thick in Lebanon area).

Myerstown limestone

Gray-tan, thin bedded limestone, graphitic at base, usually medium to finely crystalline (250 feet thick in Lebanon area).

Annville limestone

Light gray, high calcium limestone, massive or thick-bedded, weathers to white sugary-appearing surface (450 feet thick in Lebanon area).

Lower Ordovician

Beekmantown group

Ontelaunee, Epler, Rickenbach, and Stonehenge formations comprise this group in the Lebanon area. Light to dark gray limestone and dolomite with crystalline and fossiliferous beds; some dark gray chert and edgewise conglomerate (2000-2500 feet thick). Contains *Isochilina seelyi* (Whitfield), *Turritoma* sp., *Ophileta* sp., *Lophospira* sp., *Eccyliopterus* sp., *Orospire* sp., *Maclurites oceanus*, *Cryptozoon steeli*.

CAMBRIAN

Upper Cambrian

Conococheague limestone

Impure, dark-blue limestone, with bands of black chert, oolites, edgewise conglomerates, and cryptozooan reefs; contains several dolomite beds. (Subdivided into following members in northern Lancaster and adjacent counties: Richland, Millbach, Schaefferstown, Snitz Creek, and Buffalo Springs members.) Contains *Cryptozoon proliferum* and *C. undulatum* (1000-1500 feet thick).

Middle Cambrian

Elbrook limestone

Thin-bedded, shaly, laminated, fine-grained argillaceous limestone and dolomite; weathers to buff surface (approximately 1000 feet thick).

Lower Cambrian

Ledger dolomite

Light gray to white coarsely crystalline dolomite; weathers to rough sugary surface (approximately 1000 feet thick).

Kinzers formation

Dark banded argillaceous dolomite, spotted marble, and dark calcareous shale; contains many Lower Cambrian fossils including Bonnia, Olenellus, Wanneria, and Paedumias (0-500 feet thick).

Vintage dolomite

Gray thick bedded, knotty dolomite with argillaceous partings and marble at base. Contains Salterella conica. (up to 600 feet thick).

Antietam quartzite

Gray-tan quartzite and quartz or mica schist with a calcareous, ferruginous, vitreous, granular quartzite at the top (200-800 feet thick). Contains Olenellus, Camerella, Obolella, Hyolithes, Scolithus.

Harpers phyllite

Fine-grained albite schist, gray-green, quartzose phyllite, dark shale and slate (approximately 1000 feet thick).

Chickies quartzite

Thick-bedded, light colored, vitreous quartzite; locally schistose with sericite partings and interbedded black slate. Contains Scolithus linearis. (500-600 feet thick)

Hellam conglomerate (not well developed in Lancaster County)

Milky-quartz pebbles up to six inches long in finer quartz-sericite matrix; some pebbles and cobbles of red and black jasper and quartzite and some bluish-green quartz.

PRECAMBRIAN

Crystalline basement complex

Baltimore gneiss, Byrum gneiss, Pickering gneiss, Pochuck gneiss, metadiabase, gabbro, graphitic gneiss, anorthosite, granodiorite, quartz monzonite, and serpentine.

ROCKS OF QUESTIONABLE AGE (Probably Lower Paleozoic)

Glenarm Series

Peach Bottom Slate

Dark bluish-gray to bluish black slate, consisting of muscovite, quartz, andalusite, and graphite with some magnetite and pyrite.

Cardiff Conglomerate

Quartz pebbles in schistose fine quartz, sericite, and chlorite matrix.

Peters Creek Schist

Chlorite and sericite quartz schists with schistose quartzites and conglomerates.

Wissahickon formation

Light gray to bluish gray mica schist with abundant biotite, muscovite, quartz, epidote, oligoclase, albite, hornblende, and chlorite.

Cockeysville Marble

White to light bluish gray marble.

Setters Formation

White feldspathic quartzite with gray mica gneiss and schist.

STOP 1. THE PORT DEPOSIT GRANODIORITE COMPLEX

C. A. Hopson
Johns Hopkins University

Pre-Silurian schist, gneiss, amphibolite, gabbro, and ultramafic rocks underlie much of the inner Piedmont along the line of Washington, Baltimore, and Philadelphia. Intrusive granitic rocks, ranging from quartz diorite to granite, penetrate them along this zone. The assemblage of granitic rocks in northeastern Maryland has been called the "Port Deposit granodiorite complex" (Hershey, 1937), but similar rocks continue along strike southwestward into Virginia and northeastward into Delaware. Rocks of the complex were studied in reconnaissance by Grimsley (1894), Bascom (1902, 1905, 1920, 1935), and Insley (1928), and their structures mapped and studied in detail by Hershey (1937).

The Port Deposit complex consists of numerous bodies of intrusive granodiorite and quartz diorite, emplaced into gabbro, metadacite, and pelitic and sandy metasedimentary rocks of the upper greenschist facies. Coarse, strongly foliated biotite granodiorite ("Port Deposit granodiorite") forms the bulk of the complex, but other plutonic and dike rocks occur as well. Hershey finds the following intrusive sequence: (1) hornblende granodiorite, (2) hornblende-biotite granodiorite and quartz diorite, (3) biotite granodiorite, and (4) massive biotite granodiorite, followed by the dike sequence (5) pegmatite and aplite, (6) granite porphyry, and (7) hornblende lamprophyre. All plutonic rocks but the youngest (4) are strongly foliated; some are intensely granulated and recrystallized.

The Port Deposit Granodiorite Complex
(Continued)

Granitic rocks of the complex have not been directly dated, but an early Paleozoic age seems likely. Similar granitic plutons in the Baltimore-Washington area, dated radiogenically, range from 350 to 550 m.y. old (Tilton, Davis, and Wetherill, 1959, and unpublished). Plutons there are older than about 425-450 m.y. are concordant, partly recrystallized gneissic quartz diorites and potash-poor granodiorites, while those younger than about 400 m.y. are discordant, undeformed potassic granodiorites and quartz monzonites. The Port Deposit granodiorite corresponds closely to the older group, both as to field and petrographic relations, and may be of similar age. This, following latest estimates of the geologic time scale (Faul, 1960; Kulp, 1959) would be about Cambrian or early Ordovician.

Cloos and Hershey (1936) considered the granodiorite to be post-Conestoga (upper Ordovician), from structural relationships. Solidification of the main Port Deposit pluton, they believed, occurred after the development of fracture cleavage in the wall rock schists. This cleavage they traced almost continuously to the Safe Harbor area, 17 miles to the northwest, where it transects Conestoga limestone.

The Port Deposit quarry is situated in the interior of a large, essentially concordant pluton (see figure 3) and exposes typical well foliated biotite granodiorite. The pluton intrudes fine grained biotite-chlorite-muscovite-albite-quartz schist and quartzite on the west and north, metadacite on the east, and gabbro on the south.

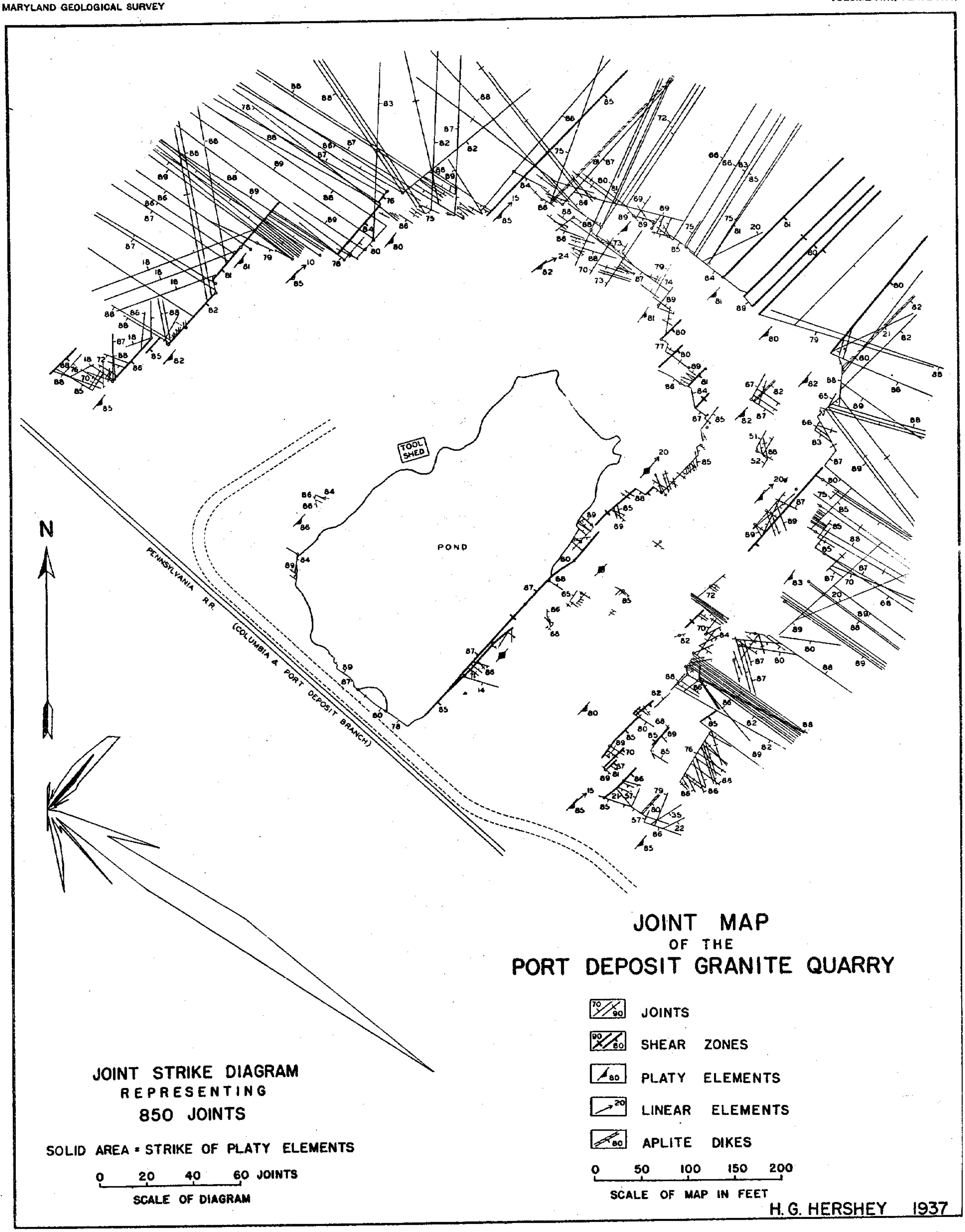

N
TOOL SHED
POND
PENNSYLVANIA R.R. (COLUMBIA & PORT DEPOSIT BRANCH)
JOINT STRIKE DIAGRAM
REPRESENTING
850 JOINTS
SOLID AREA = STRIKE OF PLATY ELEMENTS
0 20 40 60 JOINTS
SCALE OF DIAGRAM
JOINT MAP
OF THE
PORT DEPOSIT GRANITE QUARRY
JOINTS
SHEAR ZONES
PLATY ELEMENTS
LINEAR ELEMENTS
APLITE DIKES
0 50 100 150 200
SCALE OF MAP IN FEET
H. G. HERSHEY 1937

FIGURE 2

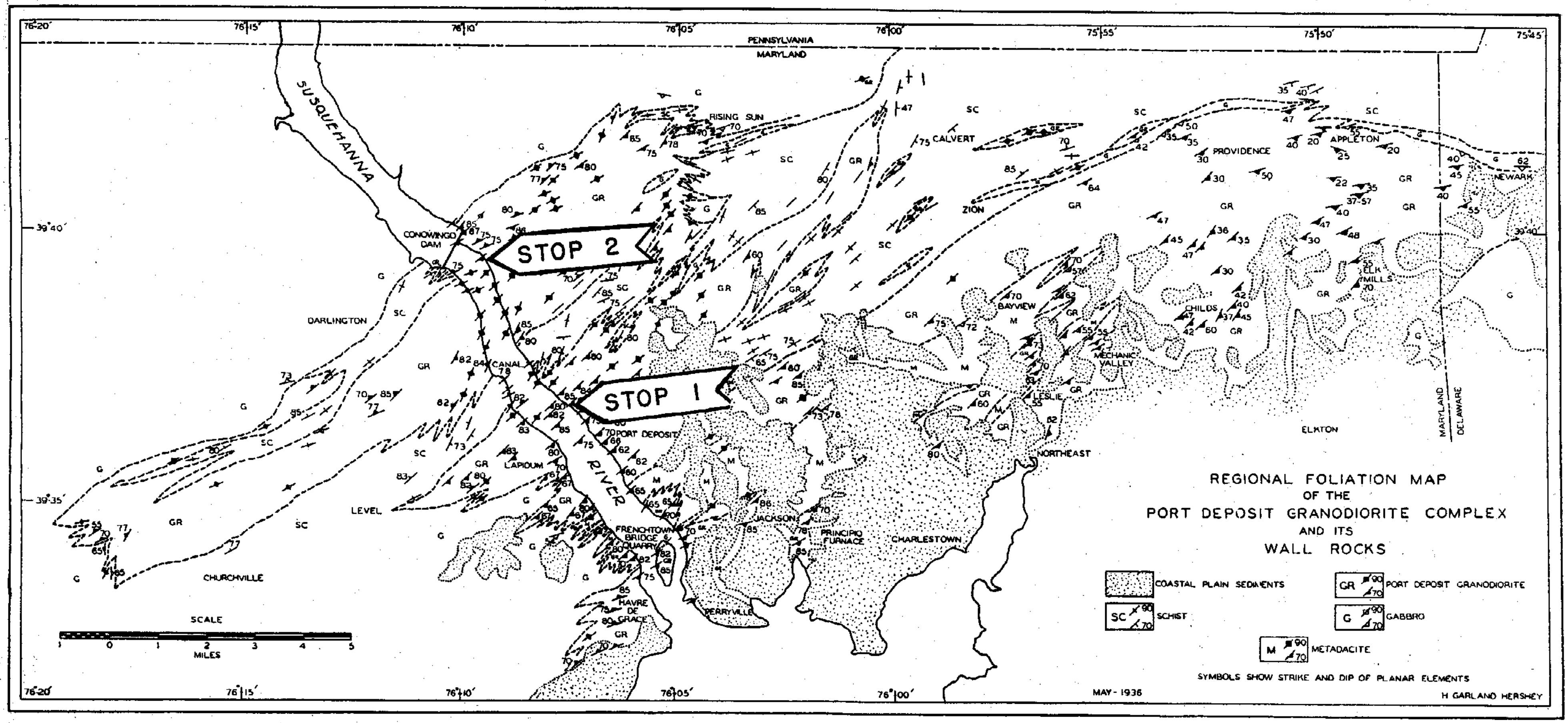

REGIONAL FOLIATION MAP
OF THE
PORT DEPOSIT GRANODIORITE COMPLEX
AND ITS
WALL ROCKS
STOP 1
STOP 2
SUSQUEHANNA
RIVER
PENNSYLVANIA
MARYLAND
DELAWARE
CONOWINGO DAM
DARLINGTON
CHURCHVILLE
LEVEL
CANAL
LAPIDUM
PORT DEPOSIT
FRENCHTOWN
BRIDGE & QUARRY
HAVRE DE GRACE
PERRYVILLE
JACKSON
PRINCIPIO FURNACE
CHARLESTOWN
NORTHEAST
RISING SUN
CALVERT
ZION
BAYVIEW
LESLIE
MECHANIC VALLEY
CHILDS
ELKTON
PROVIDENCE
APPLETON
ELK MILLS
NEWARK
COASTAL PLAIN SEDIMENTS
SC SCHIST
GR PORT DEPOSIT GRANODIORITE
G GABBRO
M METADACITE
SYMBOLS SHOW STRIKE AND DIP OF PLANAR ELEMENTS
SCALE
MILES
1 0 1 2 3 4 5
76°20′
76°15′
76°10′
76°05′
76°00′
75°55′
75°50′
75°45′
39°40′
39°35′
MAY - 1936
H GARLAND HERSHEY

FIGURE 3

The Port Deposit Granodiorite Complex
(Continued)

Table 1

Port Deposit Granodiorite. Average modal composition

Plagioclase (An_{40-15})	32%
Microcline	10
Quartz	38
Biotite	10
Muscovite	2
Epidote	6
Myrmekite, Garnet, Sphene, Allanite, Apatite, Zircon	2
	100

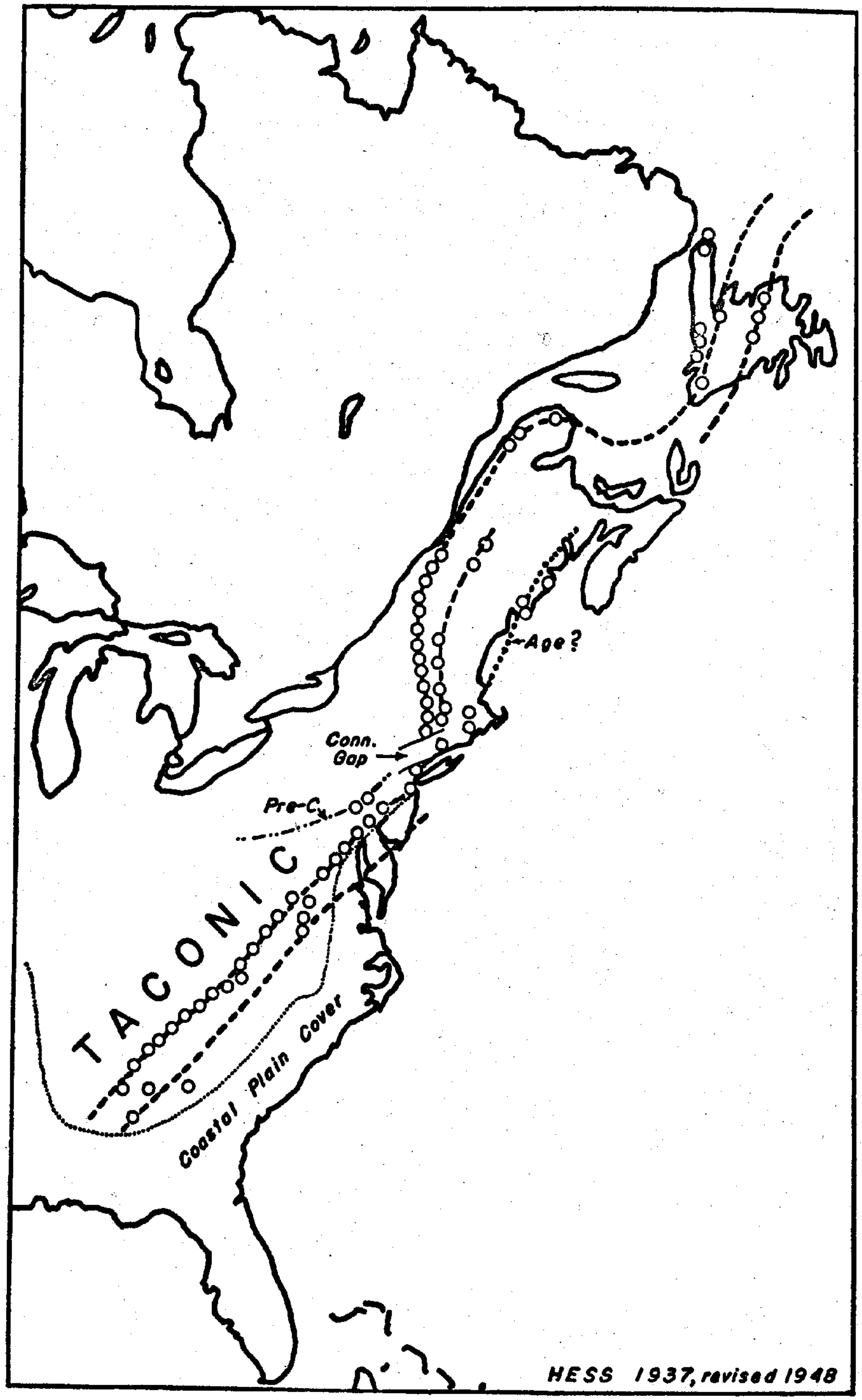
The granodiorite's magmatic parentage is shown by its sharp, intrusive contacts, its relict texture showing a magmatic crystallization sequence, its progressively zoned plagioclase (and allanite) with sharply euhedral internal zones, and by its exceptionally homogeneous character (no migmatite or nebulite zones) throughout the pluton's interior. The primary igneous texture, with quartz and perthitic microcline molded around euhedral plagioclase, biotite, and allanite, is rarely well preserved; more commonly it has been partly to completely obliterated by granulation and recrystallization.

The origin of the granodiorite's foliation has been interpreted differently. Early workers, noting its concordance to schistosity of the enclosing metamorphic rocks, assumed that it was due to a post-intrusive period of deformation. Their name for the rock, "granite gneiss," reflects its supposed metamorphic character. But Hershey believed the foliation was essentially a magmatic flow structure, because: (1) At discordant contacts the granodiorite's foliation cuts across the wall rock schistosity, parallel to the contact itself. (2) The granodiorite's foliation, commonly, becomes more intense towards the contacts, fainter toward the interior of the plutons. (3) Schistosity and fracture cleavage in the wall rocks formed before granodiorite intrusion; cleavage is transected at granodiorite contacts, and contained in xenoliths which have been rotated.

But the granodiorite's texture reflects considerable granulation and recrystallization. Original feldspars are bent and broken with smeared out tails, while "puddles" of interstitial quartz, originally large crystals, are now sutured aggregates of small, highly undulent grains. Some granodiorite, still more intensely deformed, has lost nearly all trace of original igneous texture: recrystallized quartz is segregated into pods and lenses (see photomicrograph), and biotite into elongate aggregates of tiny flakes. Unzoned granoblastic oligoclase, with associated granular epidote, small muscovite flakes, and tiny garnets, take the place of original zoned plagioclase. Granoblastic microcline is nonperthitic.

This obvious deformation, clearly recognized by Hershey, need not be ascribed to a completely later metamorphism. Protoclastic deformation, accompanying intrusion, accords better with observed contact relations. Possibly the granodiorite was syntectonic, with magmatic flowage passing into protoclastic

Figure 4. Photomicrograph of deformed and recrystallized Port Deposit biotite granodiorite, from the Port Deposit quarry (STOP 1). Except for a few shattered relict plagioclase crystals (P), all vestige of the former igneous texture is destroyed. Recrystallized quartz (Q) is segregated into prominent pods and lenses. Crossed nicols. X15.



Serpentine belt of the Appalachians. By H. H. Hess, Princeton

FIGURE 5

granulation, in turn passing indistinguishably into metamorphic deformation and recrystallization as the mass became sufficiently competent to transmit regional deforming stresses.

Tiny, closely spaced shears, transecting the foliation at a 5° to 30° angle, reflect further deformation. These are visible in rocks throughout the quarry, and are especially conspicuous where they cut across pods of quartz and aplite. Because biotite (completely unstrained) has grown along these planes, shearing probably followed the earlier deformation closely, while temperatures were still high. Possibly they are related to intrusion.

Hershey recognized several types of joints: (1) steep joints and shear zones, commonly mineralized, which cut granodiorite but not wall rock. These, he believed, were formed at the end stage of intrusion. (2) Flat joints, probably due to exfoliation. (3) Steep joints, cutting wall rock as well as granodiorite. These, he believed, were due to later regional stresses. (4) Feather joints, associated with small normal faults.

(For References see following article.)

STOP 2. CONOWINGO CONTACT ZONE, PORT DEPOSIT GRANODIORITE

C. A. Hopson
Johns Hopkins University

The location is on the east shoreline of the Susquehanna River, 800 yeards downstream from Conowingo Dam. The Dam itself is situated at the border of a northeast trending pluton of Port Deposit granodiorite, 15 miles long and 2-3 miles wide. From the dam southwestward for many miles the pluton is concordantly bordered on the northwest by steeply dipping metasedimentary rocks, but here the pluton cuts discordantly across them (see figure 3). The metasediments, chlorite-muscovite schists withthin quartzite interbeds, have been split apart like the pages of a book and invaded by quartz diorite and granodiorite. Interpenetrating granitic rocks and schist are exposed along the river's east shoreline for over one-half mile, from Conowingo Dam downstream.

Stop 2, within this contact zone, exposes granitic-appearing rocks full of inclusions, mapped by Hershey (1937, Pl. XI) as quartz diorite. The inclusions, mainly quartzite, he interpreted as xenoliths. Some have reaction rims, others are feldspathized, and others have cleavage obliterated around their margins by recrystallization; these effects he ascribed to reaction with the magma.

The granitic-appearing rocks, comprised of quartz, muscovite, albite-oligoclase, biotite, chlorite, epidote, and garnet, grade locally to finer grained, more schistose rocks resembling closely the country rock schist. Perhaps, then, they might not be igneous but metasedimentary rocks, and the inclusions be fragments of (1) sedimentary origin, or (2) tectonic origin. Nearer Conowingo

Conowingo Contact Zone, Port Deposit Granodiorite (Continued)

Dam, thin quartzite beds in pelitic schist are boudinaged, some so intensely that the boudins are separated several feet. Perhaps the quartzite "inclusions" at Stop 2 are also boudinaged fragments, but here the original beds cannot clearly be recognized. "Swarms" of inclusions along some zones could be remnants of intensely boudinaged beds.

Biotite quartz diorite carrying gabbroic inclusions, and very dark biotite-hornblende quartz diorite with hornblendic schlieren, crop out locally at Stop 2 but their contact relations are not well exposed. Along the shoreline nearer Conowingo Dam these rocks intrude schist, and locally feldspathize it on a small scale.

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STOP 3
GEOLOGY OF THE CEDAR HILL SERPENTINE QUARRY

Davis M. Lapham
Pennsylvania Geological Survey

The Cedar Hill serpentinite is within the easternmost serpentinite belt of two such belts which trend northeast from Maryland into Pennsylvania. The western belt trends approximately N30°E, is about 4 miles long, and is composed of small serpentinite lenses separated by the Peters Creek Formation. The eastern serpentinite is essentially continuous, extending northeastward from the Susquehanna River for about 15 miles and trending about N80°E. Although the major rock type in the eastern belt is serpentinite, minor ultramafics such as harzburgite, dunite, pyroxenite, peridotite, and mica peridotite are present northeast of Cedar Hill. They are in part serpentinized. Southeast of Cedar Hill the major part of the serpentinite has been silicified by microcrystalline quartz (chalcedony, "chert", jasper, etc).

At Cedar Hill the contact with the Peters Creek Schist lies just to the north of the quarry. Further to the east the serpentinite is in contact with Wissahickon Schist. Both schist formations are believed to be lower Paleozoic in age, the younger Peters Creek resting synclinally above the Wissahickon and apparently containing more quartzose interbeds. The serpentinite contact is parallel to the schistosity which ranges from nearly vertical to steeply dipping to the southeast. Massive chlorite and talc, with or without chlorite-talc schist, are universally present at the contact. The Peters Creek Schist generally becomes gneissic as the serpentinite contact is approached.

Gabbro, diorite, and granodiorite lie to the south of the serpentinite and parallel the trend of the serpentinite belt. They are presumed to be younger than the serpentinized ultramafic. About one-half mile east of Cedar Hill near the southern serpentinite contact, the gabbro contains parallel bands of coarse hornblendite in a fine-grained, gabbroic matrix. Although the origin of these bands is not known, it is possible that they represent flow banding, or layering, in the mafic complex.

Both the igneous complex and the adjacent schists are transected by numerous granitic pegmatities containing minerals such as quartz, feldspar, tourmaline, epidote, and muscovite. A zoned pegmatite may be seen in the northwest corner of the Cedar Hill quarry parallel to a dominant fracture system. The center of the pegmatite is coarsely crystallized vermiculite rimmed by chlorite at the serpentinite contact. Elsewhere feldspar is occasionally found within the center of the vermiculite zone. Magnetite fracture fillings associated with sheared antigorite are also present in the Cedar Hill Quarry.

Throughout the quarry low temperature fracture fillings are common. They are crudely zoned with a narrow rim of chalcedony, an intermediate zone of massive magnesite and dolomite, and a central area of cavities containing stalactitic magnesite, deweylite (massive and pseudomorphous after aragonite), aragonite, and hydromagnesite. Brucite and rarely hydromagnesite crystals also can be found along fracture surfaces.

The serpentinite contains disseminated magnetite and remnant olivine grains exhibiting a boxwork structure of antigorite and limonite. Weathering results in a typical spotted texture as a result of aggregated magnetite clouding. At least two generations of antigorite and one of chrysotile appear to be present. Chlorite is common. South of Cedar Hill quarry in a pit along the bank on the west side of Octoraro Creek, disseminated grains and veinlet trails of chromite are present within the serpentinite. This pit was a chromite prospect and is known as the Geiger quarry.

The Cedar Hill serpentinite is one of many similar masses extending along the eastern seaboard into Canada and Newfoundland which have been referred to the Alpine type. Two criteria used by Hess (1955, p. 394) to differentiate alpine peridotites from the differentiates of the Bushveld type are the almost complete absence of feldspathic differentiates and a lack of alnoites, kimberlites, and mica peridotites in the alpine type. A small area of mica peridotite is present southwest of Cedar Hill in Maryland. Feldspathic igneous rocks are present to the south. Hence, the question of criteria and classification of this serpentinite may be raised. Other unsolved problems common to these serpentinites include the relation of the ultramafics to the Taconic orogeny, the mode of intrusion of an original ultramafic, the time of serpentinization relative to intrusion, the relation of these two events to the regional metamorphism, a possible genetic relation among the ultramafics, mafics, granitoid rocks and granitic pegmatities, and the extent to which chromite may have crystallized in a post magmatic phase.

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STOP 4. THE MARTIC PROBLEM AND THE NEW PROVIDENCE RAILROAD CUT

Speaker: Ernst Cloos
Johns Hopkins University

Notes: Donald U. Wise
Franklin and Marshall College

I. Introduction.

A. The "Martic Line" is the line of contact between rocks of uncertain age of the Glenarm series to the southeast with rocks of known Cambro-Ordovician age to the northwest.

1. The line takes its name from nearby Martic Township in Lancaster County.

2. This general line of contact can be traced for hundreds of miles along the Appalachians.

B. The Martic Problem concerns the nature of this line and its bearing on the age of the Glenarm series--Precambrian (?) or Paleozoic (?).

1. Age of the Glenarm is of general tectonic interest in deciding whether this part of the core of the Appalachians was elevated (Precambrian age of Glenarm), suffered major depression (Paleozoic age of Glenarm) or represents some mixture of both elevation and depression.

C. New Providence Railroad Cut is one of the best exposures of the "Martic Line" or Martic Contact.

1. Clearly shows that the Wissahickon schist of the Glenarm series here rests on top of the Conestoga limestone of Ordovician age.

2. Knopf and Jonas (1929) believed the Glenarm series to be Precambrian in age and hence interpreted this contact of "older" over"younger" rocks to be a thrust--"THE MARTIC THRUST".

3. Miller (1935) and many other authors believed the Glenarm series to be of Paleozoic age and hence interpret the contact to be essentially depositional, perhaps unconformable.

D. This debate of relative age and of thrusting versus unconformity is the heart of the Martic Problem.

The Martic Problem and The New Providence Railroad Cut (Continued)

II. Nearby structures having bearing on the Martic Problem. Much of this work was by Cloos and Hietanen (GSA Special Paper 35).

A. The Cambro-Ordovician stratigraphy is repeated five times in front of the Martic Line (see figure, p. 53).

1. This has the appearance of thrust imbrication and is so designated on the New Pennsylvania Geological Survey map of the state.

2. In nearby Refton Cave the Cambrian Antietam schist of one of these sheets can be seen to rest on the Ordovician Conestoga limestone of the next lower sheet.

3. These appear to be five thrusts which were early stage features that subsequently have been folded (see figure p.53) and metamorphosed.

B. The structurally highest thrust sheet includes a ridge of Antietam schist which Cloos has traced parallel to the Martic Front for a distance of 18 miles (with one gap of a few hundred yards).

1. This is the ridge that was crossed in the highway cut 2.2 miles before reaching this location.

(a) This ridge of Cambrian Antietam schist is both overlain and underlain by the Ordovician Conestoga limestone.

2. The sinuous nature of the ridge gives some indication of the post-thrust folding.

3. At Quarryville this ridge merges with the Wissahickon schist at the Martic Front.

(a) The two schists are so similar in appearance and exposure is so poor at the Quarryville junction that no direct evidence of the nature of the junction is available there.

4. There are three structural possibilities for this Quarryville junction.

(a) First: The relationship may be entirely stratigraphic with the junction resulting from the eastward pinch-out of the limestone which separates the Antietam and the Wissahickon schists.

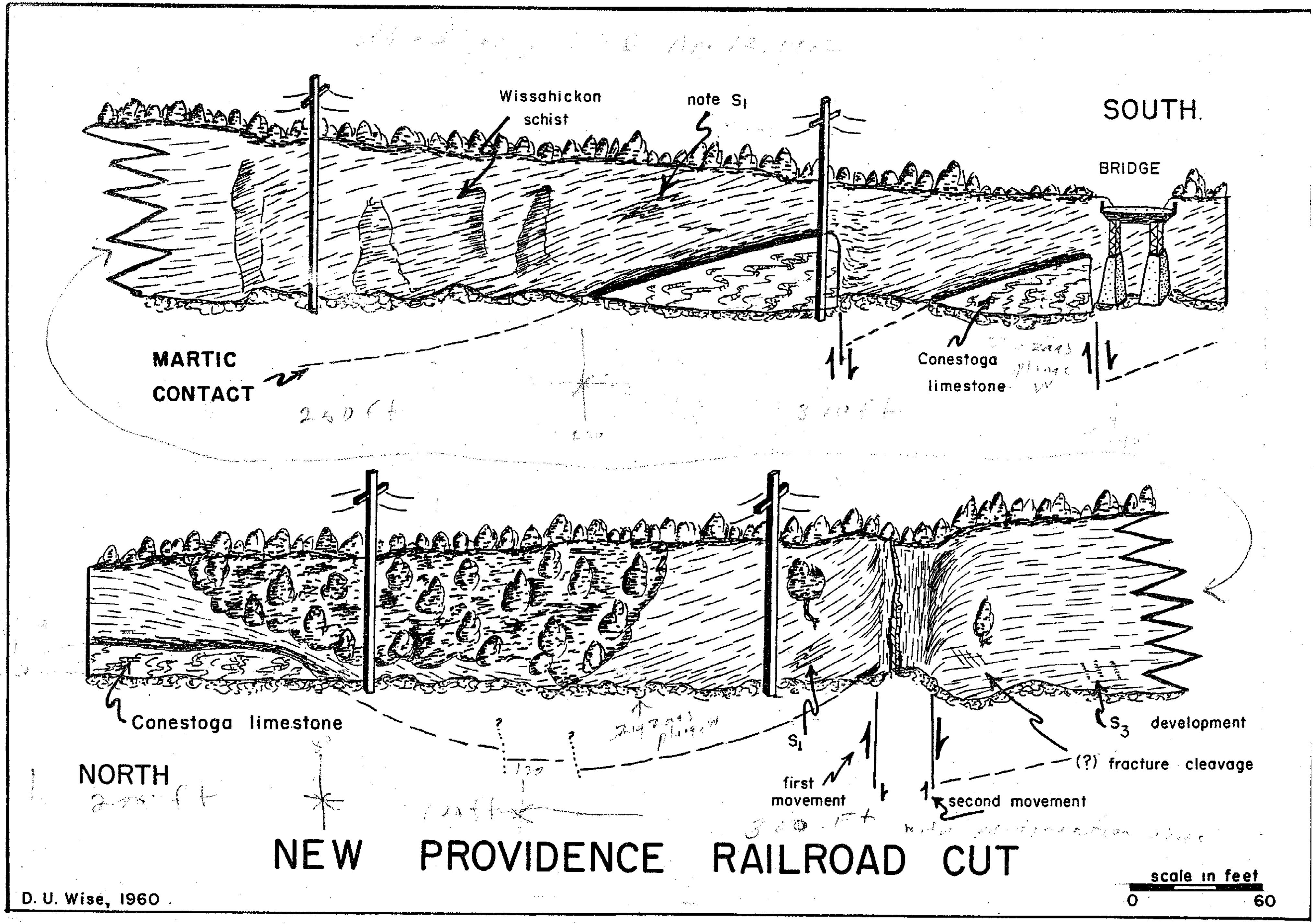
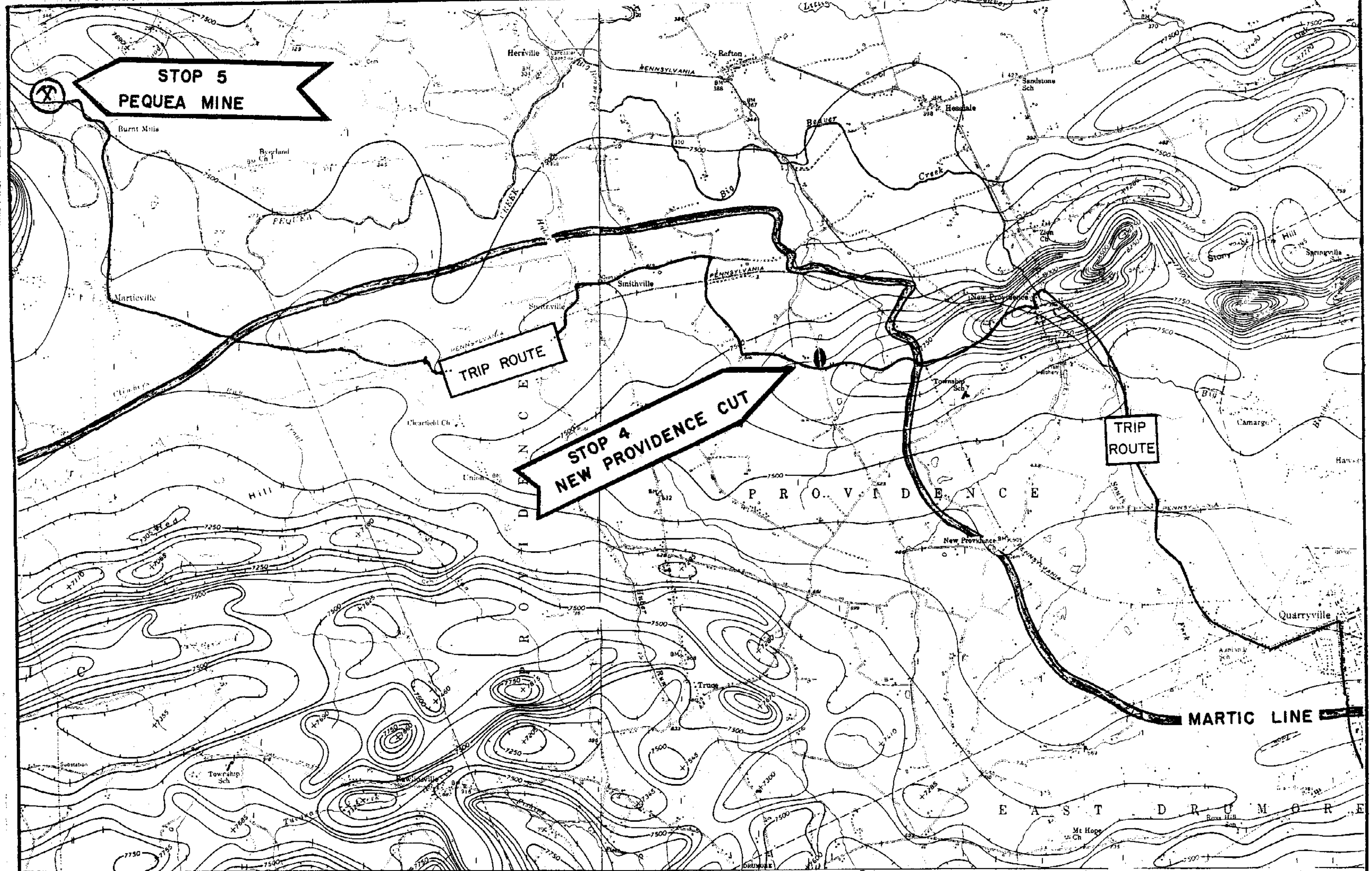

SOUTH.
BRIDGE
Wissahickon schist
note S_1
Conestoga limestone
MARTIC CONTACT
NORTH
Conestoga limestone
S_1
first movement
second movement
(?) fracture cleavage
S_3 development
NEW PROVIDENCE RAILROAD CUT
D. U. Wise, 1960
scale in feet
0
60

FIGURE 6



NOTE

Aeromagnetic data are obtained and compiled along a continuous line, whereas ground magnetic surveys are made at separate points. Errors within the normal limits of any magnetic measurement may cause slight discrepancies between flight lines in an aeromagnetic map, which would be more obvious than similar discrepancies between points in a ground magnetic map. For this reason as much care should be exercised in evaluating magnetic features that appear as elongations along a single aeromagnetic traverse as in interpreting an anomaly indicated by a single ground station.

AEROMAGNETIC MAP OF THE QUARRYVILLE-CONESTOGA QUADRANGLES
LANCASTER COUNTY, PENNSYLVANIA

By

Randolph W. Bromery, Gerald L. Zandle, and others

SCALE 1:24 000

CONTOUR INTERVAL 50 GAMMAS

1959

Base map by Topographic Division
U. S. Geological Survey

APPROXIMATE MEAN DECLINATION, 1959

GEOPHYSICAL INVESTIGATIONS
MAP GP-218 MAP GP-219

FIGURE 7

The Martic Problem and
The New Providence Railroad Cut
(Continued)

(1) The possibility implies gross error in the correlation of the Cambro-Ordovician stratigraphy of the area.

(2) There are some calcareous schists in the Wissahickon so some possibility of miscorrelation exists.

(3) A major unconformity is known to separate the Conestoga limestone from the Antietam schist so the stratigraphy is not this simple.

(4) The five time repetition must still be explained by some thrusting although a faint possibility exists for isoclinal folding to have caused the repetition.

(b) Second: The Quarryville junction may represent a folded unconformity of the Wissahickon schist across the beveled end of the highest of the five thrust sheet repetitions.

(1) Thrusting of the magnitude necessary to produce the five repetitions would probably so disturb the area that a simple unconformity paralleling the topmost sheet is unlikely.

(c) Third: The Martic Contact here may be merely the sixth thrust in the same system with the five thrusts beneath it. At the junction this highest, sixth thrust is cutting across the sheet below it, possibly as a result of the influence of an initial slight rise of Mine Ridge.

(1) This Martic contact on top of the next sheet beneath it extends perpendicular to the strike of the present fold axes for a distance of 4 miles. The implication is of a minimum of 4 miles displacement on the thrust of the Martic contact.

(2) The 4 mile figure should not be taken too seriously for implicit in it is the assumption that the thrusting took place perpendicular to the present fold axes. These folds are superimposed on the thrust sheets and may have little or no relationship to the earlier direction of thrusting.

The Martic Problem and
The New Providence Railroad Cut
(Continued)

C. A linear valley exists in the Wissahickon schist just south of and parallel to the Martic Front curving with the front around the nose of Mine Ridge.

1. Part of the field trip route to the next stop runs for several miles along this valley.

2. The valley appears to be controlled by weathering out of a calcareous schist.

3. Knopf and Jonas (1929) interpreted this as the Conestoga limestone appearing in a linear window through their "Martic Thrust".

4. It is difficult to see how the axis of the cross structure necessary to create such a window could be refolded to have so perfect a parallelism to the front.

5. It seems much more likely that this represents a slightly more calcareous unit in the Wissahickon stratigraphy, refolded so that it now parallels the Martic contact.

   (a) Implication is that the Martic Contact in this area is roughly parallel to the bedding in the former sediment from which the Wissahickon schist was produced.

D. Magnetic Data.

1. Recently completed by the U.S. G.S., Bromery, et al (1959). (See figure 7.)

2. Shows two distinct textural patterns to the magnetic contours in the area.

   (a) The zone in front of (north) the Martic Contact is characterized by a relatively uniform magnetic field with some magnetic highs parallel to fold axes, particularly those in the Antietam schist. In the vicinity of New Providence this pattern persists for two miles into the outcrop area of the Wissahickon schist. THE BOUNDARY BETWEEN THE TWO MAGNETIC PATTERNS IS OFFSET BY ABOUT A MILE FROM THE SURFACE OUTCROP OF THE MARTIC LINE. This indicates that the Wissahickon schist cover in this area is a relatively thin sheet which could not mask the magnetic effects of the material beneath it--a conclusion in good agreement with the field evidence.

The Martic Problem and
The New Providence Railroad Cut
(Continued)

more likely in the underlying basement

(b) The Wissahickon schist is dominated by a "curly maple" pattern of magnetic highs and lows in complex curling arcs. A distinct series of linear "highs and lows" occur about a mile south of the Martic front. This implies that there are magnetic differences in units of the Wissahickon schist which run roughly parallel to the contact.

E. There is no metamorphic discontinuity at the Martic Line.

1. Petrofabrics are essentially the same on both sides.

2. The metamorphic pattern is of a regional nature generally decreasing in intensity from south to north.

F. The axial planes of the minor folds and the related schistosity are not what might be expected in a zone of south to north thrusting.

1. These planar features form a broad fan across the Lancaster Valley so that in the southern portion, near the Martic Front, these planar structures dip moderately to the north--away from the supposed source of thrusting.

2. The reason for this fanning is unknown, but it seems to be independent of the stratigraphic repetitions.

3. The relationship supports the petrofabric evidence that the schistosity and tight folding are younger structures superimposed on the five stratigraphic repetitions as well as on the Wissahickon schist.

G. Long term continued uplift of basement in the Mine Ridge Anticline.

1. Mine Ridge is an anticlinorium plunging S70°W at about 15° with the Precambrian Baltimore gneiss exposed in its core.

2. There are questionable indications of an early effect of Mine Ridge uplift in determining the positions and terminations of the five thrust repetitions (noted in item II-A).

3. The minor folds of Mine Ridge extend westward along plunge to involve some of the five thrust repetitions. In addition Mine Ridge is asymmetric with the steep limb on the south, a relation that fits well with the general fanning of axial planes and schistosity across the Lancaster Valley (see item II-F). The indication is that some of the Mine Ridge movement is related to the time of formation of the schistosity.

The Martic Problem and The New Providence Railroad Cut (Continued)

4. Late or Post-schistosity movements: Westward along plunge, Mine Ridge Anticline continues for at least 20 miles in the Wissahickon schist as a broad anticlinal warping of the S_2 surfaces. This westward extension is known as the Tucquan Anticline. This suggests that the last of the basement uplift along the Mine Ridge axis occurred after the cessation of S_2 development. The conclusion of extensive post-schistosity deformation is supported by many younger structures visible in the New Providence Railroad cut.

H. The gross stratigraphy of the Mine Ridge and Lancaster Area (shale over carbonate over quartzites over Baltimore gneiss) is quite similar to the Glenarm stratigraphy (Wissahickon schist over carbonate over quartzite over Baltimore gneiss) as exposed in the Avondale-Doe Run area only 6 miles south of Mine Ridge and 20 miles east of this location. (See Fig. 1)

1. The correlation of the two series across the Martic Line has been suggested in the past.

2. See Kauffman's summary of this in the following article.

III. Features to be noted at the New Providence Railroad Cut.

A. The Martic Contact is exposed as the deeply weathered Wissahickon schist resting on the blue gray micaceous Conestoga limestone of Ordovician age. (The Conestoga yields some fossils near York, Pennsylvania.)

B. Faulting of the contact.

1. Two nearly vertical faults break the contact near the railroad bridge.

2. South side down on both faults.

C. Schistosity in the Wissahickon.

1. The schistosity is roughly parallel to the contact and might be mistaken for bedding were it not for some of the weathered surfaces near the north end of the cut revealing intense folding with the schistosity parallel to the axial planes.

2. The schistosity is thus an "S_2" surface.

The Martic Problem and
The New Providence Railroad Cut
(Continued)

D. Degree of metamorphism and folding is the same in both the Wissahickon schist and Conestoga limestone.

1. Whatever the nature of the contact of the two rock units the metamorphism and folding is superimposed on both and hence younger than the contact between them.

2. This younger metamorphism seems to have obliterated any structures which formerly might have been present on the contact plane.

E. Rolled quartz vein (striking N45E) in the north end of the cut.

1. Wissahickon schistosity steepens sharply here and becomes vertical through a wide shear zone.

   (a) Rotation of the foliation may possibly indicate a drag on the fault zone. If so, it indicates the south side up.

2. Exposure of blue-gray phyllite at track level on the north side of the shear zones (west side of tracks) appears to be the Conestoga limestone, raised on the north side.

3. Enigma is that the lithology indicates one sense of displacement on the zone whereas the drag (?) indicates the opposite.

4. Quartz vein in the shear zone suffered rolling into pencil-like structures having an essentially horizontal axis. Some claim they can detect a sense of movement on slickensides associated with the vein.

5. One possible solution to the enigma is:

   (a) Early faulting with up on the north, the same as other two faults nearer the bridge.

   (b) Then injection of the quartz vein.

   (c) Younger faulting of lesser magnitude with reversed sense of displacement (up on the south). This resulted in rolling of the quartz, slickensiding (?) of it, and drag (?) of the Wissahickon schistosity.

6. This interpretation should be debated in light of the field observations and may well be rejected. However, the basic object lesson still stands--DRAG FOLDS AND

The Martic Problem and
The New Providence Railroad Cut
(Continued)

SLICKENSIDES INDICATE ONLY THE VERY LAST DISPLACEMENTS AND DO NOT NECESSARILY REFLECT THE TRUE DISPLACEMENT ALONG A DISTURBED ZONE. Nct

F. Broad warping of the schistosity indicates late or post-schistosity gentle folding in addition to the sharper faulting.

G. Younger or higher order "S" surfaces.

1. Visible on the east wall of the cut 50 feet south of the "rolled" quartz vein.

2. These look like tiny crinklings of the schistosity.

   (a) Closer examination will reveal that this crinkling occurs along definite planes and results from a slight shear and offset along the planes.

   (b) These planes are here N10E, 85W and are consistently down on the east side.

   (c) Other south dipping planes nearby appear to be a kind of post-schistosity fracture cleavage.

3. Terminology of such structures is always a problem. Should they be considered younger cleavages? Are they slip cleavage or fracture cleavage or just a type of incipient shear jointing?

   (a) A simple and non-genetic terminology is that of Sander in using the general term "S-surface" to indicate parallel planes of mechanical inhomogenity in deformed rocks.

   (b) Under this terminology the highest order of S-surface reached in the New Providence Cut is S_3.
   S_1 - stratification or bedding
   S_2 - major schistosity of the Wissahickon schist
   S_3 - here striking N10E, 85°W and down on the east

4. The features are not particularly well developed here and may merely be related to the nearby faults. However, similar higher order S-surfaces are known to occur at many places through the region (see Stop 6) but their regional sense (or senses) of shear as well as their tectonic significance is unknown.

The Martic Problem and
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(Continued)

H. The major significant conclusion from this cut is that a sequence of relative ages may be assigned to the various structural events:

1. Oldest: The rocks that have now become the Wissahickon schist were placed on top of the Conestoga limestone.

2. Then: Major deformation and flow of the entire mass created the present schistosity and folding equally in both rock types.

3. In the later stages of the flowage or subsequent to it a complex set or sets of deformations occurred involving faulting, quartz injection, and minor slip along younger S-surfaces.

IV. General Summary.

One of the major difficulties of the Martic Problem is that a number of types of stratigraphic units, metamorphic grades and structures have been superimposed one on the other. It thus becomes a problem of finding all the members of a single class as well as assigning relative ages to the different classes. On the present evidence the best tentative sequence appears to be:

(1) An early or pre-metamorphic stage superposition of stratigraphic units, most likely by imbrication of at least five and probably six sheets. The topmost or sixth sheet would be the Wissahickon schist resting on the other sheets of known age along the Martic Contact.

(2) A second stage of metamorphism, flowage, recrystallization and development of schistosity was superimposed on the entire imbricate mass. This deformation was not just a continuation of the "thrust" imbrication movement for these axial planes are north dipping in all of the units.

(3) Deeper seated basement folding and uplift along the Mine Ridge axis continued through both previous stages. It was probably very mild in stage 1, reached major proportions in stage 2 and continued strongly beyond the close of stage 2.

The overall deformation picture appears to be one of initial involvement of a sedimentary skin with increasing effect of the deeper processes of metamorphism and finally major basement involvement.

The Martic Problem and The New Providence Railroad Cut (Continued)

This is only part of the Martic Problem, the heart of which centers on the age of the Glenarm series. Unfortunately, much of the initial argument on the Glenarm age fell into the old logical trap of an either-or argument: either the Martic Contact is a thrust and the Glenarm series is Precambrian, or the Martic Contact is an unconformity and the Glenarm series is of Paleozoic age. On the basis of more recent work, particularly that of Cloos, it seems clear that there has been thrusting along the Martic zone and quite likely on the Martic Contact itself. Using the "either-or" argument this would seem to favor the Precambrian age for the Glenarm series. In reality, a third possibility exists: that the Glenarm series is largely of Paleozoic age and has been thrust relatively minor distances along the Martic zone.

In recent years this third possibility has found increasing favor. One indication of this is that the Glenarm series is listed as "probably lower Paleozoic" on the new Pennsylvania State Geological map. However, it must be emphasized again that no direct evidence on the age of the Glenarm series is now available although future work in metamorphic stratigraphy or radiometrics may bring some to light.

References: see next article.

STRATIGRAPHIC RELATIONS OF THE GLENARM SERIES

Marvin E. Kauffman
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The age of the Glenarm series of southeastern Pennsylvania and adjacent parts of Maryland has variously been given as Precambrian (Bascom, 1909; Knopf and Jonas, 1923; and others), Cambro-Ordovician (Hawkins, 1924; Mackin, 1935; Miller, 1935; Cloos and Hietanan, 1941; and Swartz, 1948), or at least as pre-Silurian (Wasserburg et al, 1957, and Coquette, 1960). Evidence in support of all these views is summarized briefly in the following paragraphs.

The major arguments that have been cited in favor of a Precambrian age for the Glenarm series are (1) the higher grade of metamorphism exhibited by the Glenarm rocks when compared to adjacent strata of unquestionable Cambro-Ordovician age; (2) the intrusion by gabbroic and granitic rocks into the Wissahickon near Philadelphia and the absence of such intrusions in adjacent Cambro-Ordovician rocks; (3) the vast differences in thickness between the Glenarm series south of the Martic line and the Cambro-Ordovician strata north of this line; and (4) thrust evidence along the Martic line.

Proponents of the Cambro-Ordovician age for the Glenarm series argue that (1) there actually is a progressive decrease in the grade of metamorphism from south to north and, rather than a sharp break at the Martic line in the grade of metamorphism, the Cambro-Ordovician strata north of the line are also slightly metamorphosed; (2) absence of gabbroic and granitic rocks in unquestionable Cambro-Ordovician rocks is a negative argument of inconclusive nature; (3) the Glenarm series resembles the Cambro-Ordovician sequence of the Lancaster area in having lower tourmaline-bearing quartzites, overlain by carbonate rocks which are in turn overlain by argillaceous strata; in addition, although the thicknesses are quite different, there is a definite trend in thickness observed from Chambersburg, through the Lancaster area, to Mine Ridge and across the Martic Line; although some faulting and even thrusting occurs at various localities along and behind the Martic line, there is no evidence of extensive overthrusting such as would be necessary to bring Precambrian rocks over rocks of Cambro-Ordovician age; the fensters of limestone appearing through the schist (Stose and Stose, 1944) are actually more calcareous layers within the Wissahickon schist and parallel the Martic line, which is a conformable boundary between the schist and the limestones. Another argument against the Precambrian age for the Glenarm series (although negative) is the lack of equivalent rocks of Precambrian age north of the Martic line in the area of the Honeybrook upland, where unquestionable Early Cambrian rocks lie directly on basement. These arguments pertain only to the Glenarm series in southeastern Pennsylvania and do not necessarily apply to all rocks called Glenarm, especially the volcanics and metasediments of eastern Frederick County which present special problems (Swartz, 1948).

A minimum age for the Glenarm series may be ascertained from radiometric studies which have dated the regional metamorphism at about 350±20 million years ago (Wasserburg et al, 1957). This age was determined from micas of the Cockeysville and Setters formations and pegmatites intruding the Glenarm series. Although there are differences in accepted ages for the geologic time chart, nevertheless this would place the Glenarm series as pre-Silurian (Coquette, 1960).

"Throughout discussion of the Glenarm problem, it must be recognized that these rocks occur under conditions of imperfect exposure, complexity of deformation, variation in intensity of deformation, original changes in lithologic characters, and lack of known fossils, so that interpretations are impeded" (Swartz, 1948).

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STOP 5. THE PEQUEA "SILVER" MINE

Donald U. Wise
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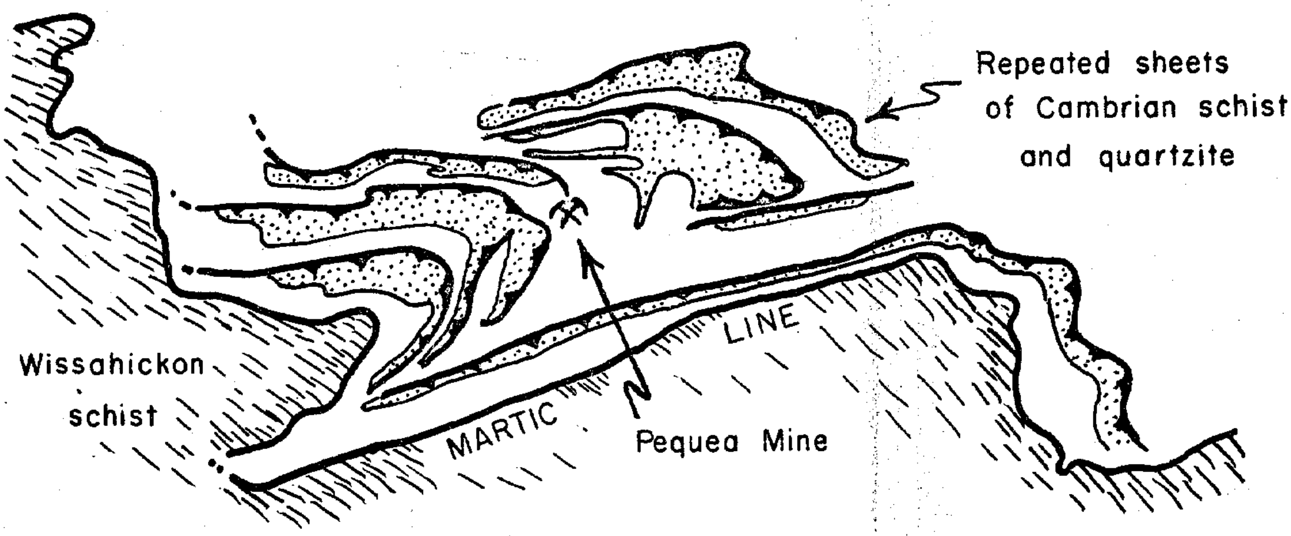
I. Chief feature here is the exposure of what appears to be a folded thrust (?).

A. Location is in the zone of imbricate thrust repetitions north of the Martic Front.

1. There are five major repetitions in the zone as mapped by Cloos and Heitanen (1941).



2. This location is in the middle or third of the five major stratigraphic repetitions (apparently repeated by thrusting).

3. The map pattern of these five repetitions implies there has been post-imbrication folding of the sheets.

4. This location is one of the few exposures at which a folded imbrication (minor) can be "walked out".

B. Permission to enter the mine area 600 feet upstream along Silver Mine Run should be requested at the farmhouse of Mr. Groff (see Road Log).

C. The area is also of interest because of the obvious structural control of quartz veins and ore deposition as well as from a historical viewpoint.

The Pequea "Silver" Mine
(Continued)

II. The folded "thrust"(?).

A. Stratigraphy.

1. Three formations.

(a) Oldest is Cambrian Antietam schist and quartzite which occurs a few hundred yards north of the mine.

(b) Cambrian Vintage dolomite: In the mine area this is a light gray to blue-gray, finely crystalline sparkling dolomitic marble, commonly mottled and massive.

(c) Ordovician Conestoga limestone: A dark blue, thinly bedded phyllitic limestone resting unconformably on the vintage dolomite. Locally there are large conglomerate breccias associated with the lower parts of the Conestoga. In many areas, including this one, the very basal zone, a few feet thick, is marked by a distinctive, organic rich, calcareous phyllite.

2. The entire thrust interpretation depends on the observation that the black basal Conestoga phyllite and the light gray mottled finely crystalline dolomite of the Vintage are two distinct rock types, each indicative of and restricted to its own formation.

(a) This is the weakest link in the thrust argument, but is supported by what is known of these formations in the nearby area and by this location in a supposed thrust zone.

B. The ore was argentiferous galena in quartz, largely localized at the unconformable contact of the Vintage dolomite with the overlying black phyllite of the Conestoga formation.

1. Some of the original prospects were expanded into small quarries for the kiln on the property.

2. Starting at the main drift, the Vintage-Conestoga <u>contact(s) may be traced</u> up over the hill slope <u>through several folds</u> by means of mine pits, prospects and quarries. (See figure 9 .)

C. The stratigraphic repetition.

1. The folded contact is actually a double contact of Conestoga over Vintage over Conestoga over Vintage.

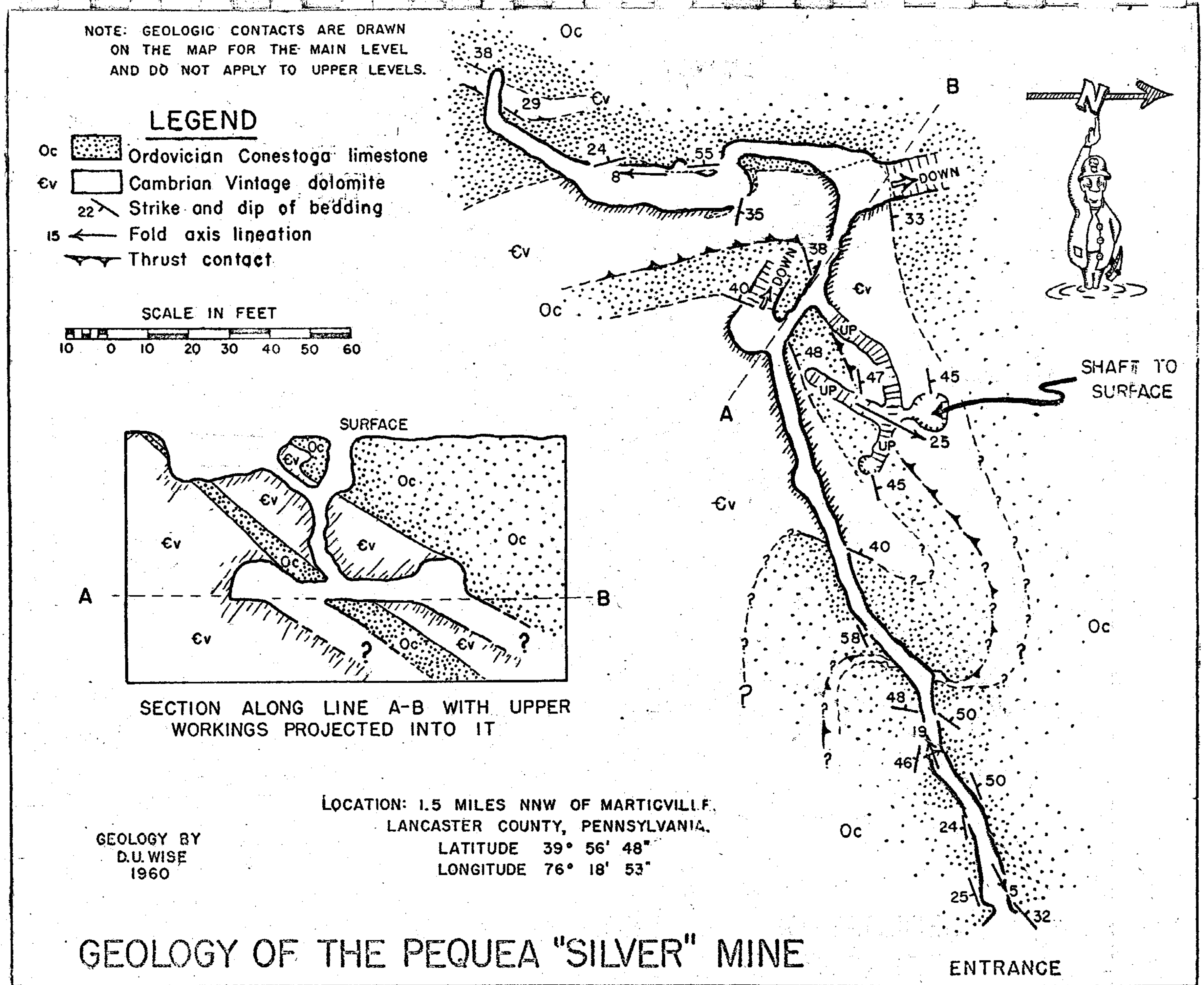
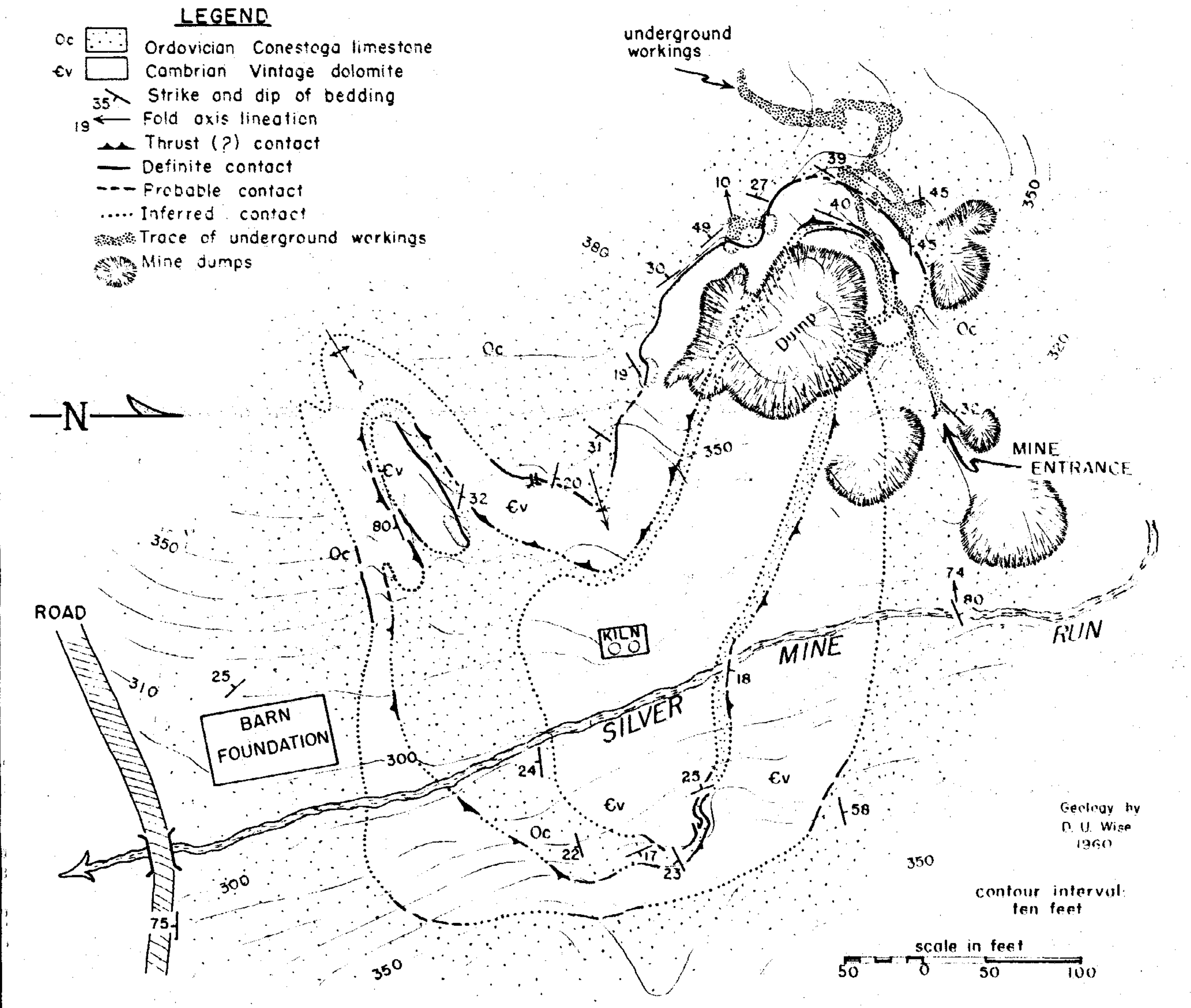

NOTE: GEOLOGIC CONTACTS ARE DRAWN
ON THE MAP FOR THE MAIN LEVEL
AND DO NOT APPLY TO UPPER LEVELS.
LEGEND
Oc Ordovician Conestoga limestone
€v Cambrian Vintage dolomite
22 Strike and dip of bedding
15 Fold axis lineation
Thrust contact
SCALE IN FEET
10 0 10 20 30 40 50 60
SURFACE
A
B
SECTION ALONG LINE A-B WITH UPPER
WORKINGS PROJECTED INTO IT
LOCATION: 1.5 MILES NNW OF MARTICVILLE,
LANCASTER COUNTY, PENNSYLVANIA.
LATITUDE 39° 56' 48"
LONGITUDE 76° 18' 53"
GEOLOGY BY
D.U. WISE
1960
SHAFT TO
SURFACE
DOWN
UP
N
ENTRANCE
GEOLOGY OF THE PEQUEA "SILVER" MINE

FIGURE 8



GEOLOGY OF THE PEQUEA "SILVER" MINE AREA

FIGURE 9

The Pequea "Silver" Mine
(Continued)

2. This is best seen in the middle portion of the main drift of the mine

   (a) See cross section in figure 8.

   (b) Two inclines were driven downward along the twice repeated unconformity of the Conestoga limestone over the Vintage dolomite.

   (c) An irregular working follows the thrust contact upwards, then steepens to cut through the repeated sheet of the Vintage dolomite and opens on the surface as a small shaft and a subsidiary "gopher hole" in the uppermost layer of Conestoga limestone

   (d) Within the "gopher hole" the workings followed a northeast plunging fold axis

3. Most of the workings are located on the crests of minor folds or zones of tighter crumpling

   (a) The folds show a very complex pattern of strikes and plunges but most have a general north or northeast strike

   (b) Some of the axial planes are quite flat approximately 60 feet from the rear of the mine, in the upper workings of the "gopher hole" and as indicated by some low dipping cleavages near the mine entrance.

   (c) The folds near the mine entrance show plunges both toward the north and toward the south.

   (d) The entire pattern is one of disharmonious folding.

4. There is abundant evidence of a period (or periods) of complex folding subsequent to the formation of the stratigraphic imbrications observed in the mine.

The Pequea "Silver" Mine
(Continued)

5. Thus in both surface and underground exposures, the folded stratigraphic repetition may be traced around most of the valley.

III. "Ore" deposition.

A. Quartz veins with minor argentiferous galena.

1. Some of the quartz shows open space fillings with greatly flattened crystal forms.

B. The quartz occurs almost entirely in the Vintage dolomite near and along the contact with the phyllite.

1. The maximum amount of quartz appears to be near the fold crest.

2. The quartz also seems to be more common in the thrust-repeated sheet of Vintage.

C. The control of the ore is largely the result of YIELD DIFFERENCES BETWEEN THE CONESTOGA PHYLLITES, which flowed without separation, AND THE MORE BRITTLE VINTAGE DOLOMITE, in which open joints were created to produce ready access for the quartz bearing solutions.

1. In effect, a "permeability trap" was created in the fold by differences in yield characteristic.

D. The close association of the quartz with the fold structure and joints implies quartz injection during or possibly after the folding period.

IV. History

Several years ago the Franklin and Marshall College Library discovered in its collection a prospectus from this operation dated 1863--Civil War Days. Excerpts from the prospectus are reproduced below.

The description of the work catches much of the excitement of that early mining and adds the human touch to what otherwise would be only a hole in the ground.

From the description it would appear that most of the work now visible had been completed at that time. The three veins described in the main drift appear to be those seen in the cross cut 125 feet from the entrance. Subsequent to that writing in 1863 another hundred feet of tunnel and the presently flooded inclines were driven, certainly not a QUARTER OF A MILLION DOLLARS of work. One cannot help but wonder if this was a lead mine as claimed in the prospectus, a silver mine as it is known locally, or just a plain "Gold mining" operation.

****

PEQUEA SILVER MINE

Excerpts - (Prospectus) Lancaster Lead Company, n.p. n.d. (1863)

Lancaster Lead Company

"Capital,	$250,000
50,000 Shares	$5.00 ea.

President, John C. Mallory
Treasurer, S. O. Howe
Secretary, J. R. Sibley

Trustees: Henry Warren
W. H. Curtis
John C. Mallory

"This company has been formed under the general Manufacturing and Mining Laws of the State of New York, and is empowered to do business in the State of Pennsylvania, where its property is situated.

"The Lancaster Lead Mine is situated at Marticville, Lancaster Co., Pa., and promises to be <u>one of the most valuable mines of the Atlantic States</u>. The occurrence of lead ores in almost all of the States has long been known, and most of the lead ores have been tested by Professor Booth, of Philadelphia. There are very few of them, whatever may be their geological relations that have not some silver, and <u>this is an indication of great value in lead mines</u>. It seems to be a rule, not only in gold and silver but in lead, that the metal is found in deposits, workings and isolated quantities, from the breaking up of veins, and these are soon exhausted. <u>It is, however, to the veins themselves that we are to look for a perpetual supply</u>. The ledges, beds, and veins of auriferous quartz, from which the floating gold is derived, <u>penetrate the rocks to such depths that they may be regarded as altogether inexhaustible</u>. It is the same with veins producing copper, in which gold is a constituent, and the same principle applies to lead that carries silver, and in which the metal is procured by regular mining.

"The common ore, from which nearly all the lead of commerce is obtained, is the sulphuret called galena - a combination of 70.55 per cent of lead and 13.45 of sulphur. It is a steel grey mineral, of brilliant metallic lustre when broken. The ore very frequently contains silver, in the form of sulphuret of that metal, and may be profitably separated when it contains 8 ounces of silver to the ton; ores of this character are known as argentiferous galena, and they have been discovered in the southeastern section of Pennsylvania, running through Chester, Montgomery, and Lancaster counties. The general course of the veins is east and west, and silver has been found in them ranging from 10 oz. to 16 oz. per ton, which gives also 80 to 82 per cent of lead, according to the following analysis by Professor Joy, the coarser grained galena giving the most, and the finer grained the least.

"These veins, coming upon the lands of the Lancaster Company, which are situated in Marticville, Lanc. Co., a little to the right of Pequa Creek, were opened under the direction of F. P. Herington, well known as an experienced and highly skilful mining engineer, on the 9th Nov. last, and on the following day a considerable amount of pure loose lead was taken out. A few days subsequently, two 6-inch veins were struck. These run parallel with each other, 7 feet apart, and two more were struck on the following day. All these have a dip of 35 degrees, and were evidently converging. A thin sheet of lead running through a soft place in rock, became more regular, strong and perpendicular. As the works progressed, the lead became more abundant, and the work more facile. The severity of the winter in that region retarded the work to some extent; but, as the spring appeared, the veins were more promising, and the product greater, with somewhat decreased expenses.

"On the 24th of March, the workmen were employed on the top drift, 10 feet wide, 22 feet deep from the surface, embracing three veins, vix., the two north veins, 2 feet apart, and the foot wall vein, which is 10 feet south from the north wall of the north vein. The surface or top of this drift is sandy soil, 4 feet in depth, and the remainder of the drift is limestone rock, 18 feet to the bottom of the drift. As fast as this body of sand and rock is removed, the ore is taken out (of a purity of 80 to 82 per cent) of the three veins, which are nearly perpendicular, dipping slightly to the north. These veins are one to three inches wide, converging to unite in one vein 3 to 6 inches wide, thus decreasing the expense, and affording a product sufficient for fair dividends on the company capital. On the 9th April a shaft was sunk 30 feet west of the drift. On the 20th April the Engineer wrote:

> 'We are now sinking the third shaft, out of which we took yesterday a considerable quantity of pure lead ore. We also took lead ore. We also took lead out of the drift.'

"On the 23rd, he wrote:

> 'We are now sinking the 4th shaft. We still continue to find the sheets of pure lead ore in the sand, and a considerable quantity in the rock. We are also driving the upper drift, and are taking out more or less each day. The vein continues in the drift, and looks more favorable.'

"The progress of the works is now daily improving in productiveness and the receipts of the company's lead in the city have already commenced. The price of freight from the mines to Philadelphia, by railroad and canal, is 18 at 25 cents per 100 pounds, and the lead is of so pure a quality that it is sent down at once rather than to smelt at the mines, to diminish the cost of transportation. At the same time the market value of the mineral increases prodigiously. The demand for the lead, not only in the cities but all over the world, has greatly increased in the last few years, not alone from the expansion of the arts, but for military purposes. In the eastern States the rapid development of water works, in the dwellings and factories, as well as for farm purposes, have vastly increased the demand for this metal. In illustration of this, influence upon the demand for lead, became very great.

"The operations of the Lancaster mines have thus far been eminently satisfactory. It is now six months since the works were commenced, and the object of the Engineer has been hitherto thoroughly to test the value of the mines, by exploring all the various veins, leads, and depositories, both near the surface and in depth, by means of a series of drifts, cross-cuts and other necessary explorations. This has been satisfactorily accomplished, and a large amount of ground has been laid out for advantageous working, as soon as the most available points for work are decided upon. Most of the ground that has been drifted or sunk sustains the conclusion that a good paying mine can be worked at little expense.

"The future production of course depends upon the continued richness of the veins, but, as we have pointed out in the former part of this scetch, it is a well known fact that veins such as those we are now working are seldom ever known to give out. The company may , therefore, look confidently forward to a continued increase of production."

STOP 6. WILLIAMSONS PARK

LATE STAGE SHEARING AND HIGHER ORDER "S" SURFACES

Donald U. Wise
Franklin and Marshall College

I. Introduction.

A. Located in Williamson's Park in Lancaster.

1. On South Duke Street at the Conestoga River.

2. Outcrops illustrated on figure 10 are just inside of and 180 feet SE of the main gate to the park.

B. Area is underlain by the very tightly folded, Ordovician Conestoga limestone.

1. Fold axes strike very consistently N70E through the Lancaster Valley (indicated by the arrows on figure 10).

2. Axial planes are here nearly vertical, part of a broad fanning of axial planes across the Lancaster Valley.

3. The exposure is typical of much of the Conestoga limestone except for the higher order "S" surfaces which are present at many places in the Lancaster Valley but which here reach a maximum in development.

C. It should be emphasized that we will be discussing cross shears and cross folds and that these are structures superimposed on the already complex fold system. THEY SHOW A STRONG TENDENCY TO BE ORIENTED PERPENDICULAR TO THE OLDER FOLD AXES.

II. Chief features of the Outcrop.

A. The purpose of this stop is to:

1. Raise the general question of higher order "S" surfaces and the later stages of deformation.

2. Discuss the time and sequence whereby jointing actually takes place in a highly metamorphosed rock by examining a spectrum of structural types from

(a) Simple cross folding of axes to

(b) Cross folding with some gash veining to

(c) Gash veining transitional into breccias to

(d) Simple calcite filled corss joints to

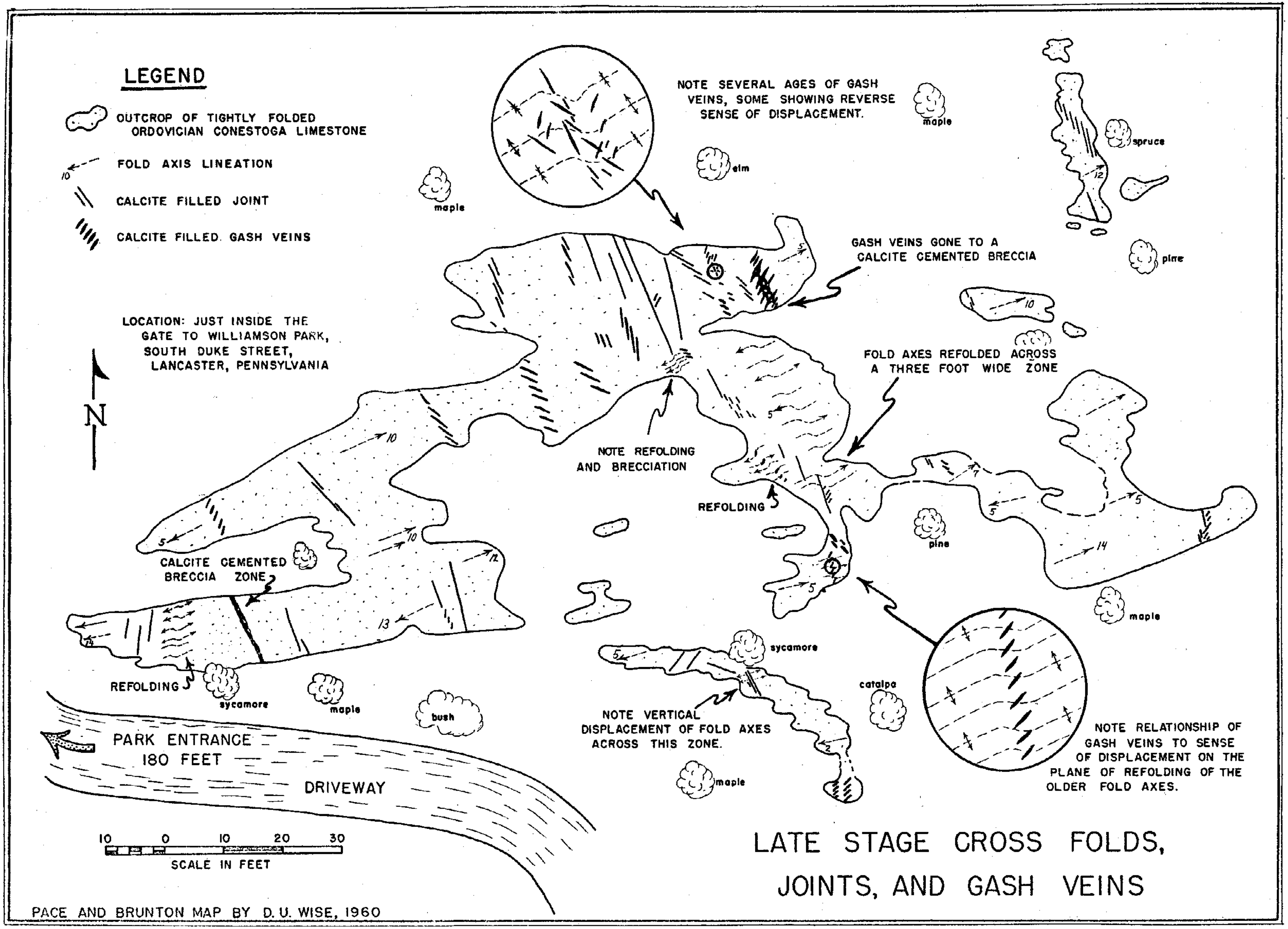

LEGEND
OUTCROP OF TIGHTLY FOLDED ORDOVICIAN CONESTOGA LIMESTONE
FOLD AXIS LINEATION
10
CALCITE FILLED JOINT
CALCITE FILLED GASH VEINS
LOCATION: JUST INSIDE THE GATE TO WILLIAMSON PARK, SOUTH DUKE STREET, LANCASTER, PENNSYLVANIA
N
NOTE SEVERAL AGES OF GASH VEINS, SOME SHOWING REVERSE SENSE OF DISPLACEMENT.
GASH VEINS GONE TO A CALCITE CEMENTED BRECCIA
FOLD AXES REFOLDED ACROSS A THREE FOOT WIDE ZONE
NOTE REFOLDING AND BRECCIATION
REFOLDING
CALCITE CEMENTED BRECCIA ZONE
REFOLDING
NOTE VERTICAL DISPLACEMENT OF FOLD AXES ACROSS THIS ZONE.
NOTE RELATIONSHIP OF GASH VEINS TO SENSE OF DISPLACEMENT ON THE PLANE OF REFOLDING OF THE OLDER FOLD AXES.
maple
elm
maple
spruce
pine
pine
maple
sycamore
catalpa
maple
sycamore
maple
bush
PARK ENTRANCE 180 FEET
DRIVEWAY
10 0 10 20 30
SCALE IN FEET
LATE STAGE CROSS FOLDS, JOINTS, AND GASH VEINS
PACE AND BRUNTON MAP BY D. U. WISE, 1960

FIGURE 10

(e) Simple cross joints.

B. This sequence is listed in order of increasingly brittle behavior of the rock and all members of the sequence are represented in the outcrops.

1. It would seem logical at first to assume that this sequence is merely an order of age of development as the rock mass became more rigid with waning metamorphic conditions.

2. This sequence may well be correct in a general way but it is difficult to support it in detail from the data observable at this outcrop.

(a) Along strike in a single zone of deformation, different members of the sequence seem to be transitional into each other. With increasing displacement along the zone more brecciation and gash veining seems to occur.

(b) Strain concentration: the total width of the disturbed zone in relation to the amount of displacement along it seems to be a factor. In the NNW trending zone, east of the center of figure 10, there is considerable displacement by cross folding but relatively little gash veining. This may be related to the fact that the displacement is distributed across a three foot wide zone.

(c) There is apparently little relationship here to the type of yeild and the sense of shear along the zone. There have been reversals of the sense of movement along the zones but there is no consistent pattern of all cross folds having right-hand sense of displacement, all gash veins left-hand sense, etc. Rather, the movement senses and the structural classes seem all mixed through each other.

C. Some of the gash veins can be observed to cut other gash veins, particularly in the area circled in the north part of figure 10.

1. Some of the more daring may wish to theorize which movement preceeded which, along this zone.

III. Terminology.

A. Sander has suggested the term "S-surface" to indicate parallel planes of mechanical inhomogenity in deformed rocks.

B. Turner and Verhoogan (pp. 533) suggest "When there is some doubt concerning their mode of origin the various sets of S surfaces that can be identified in a rock may simply be designated numerically, preferably in order of development if such is decipherable."

C. Under this system

1. The bedding of the outcrop is S_1.

2. The axial planes of the older tight folds are S_2 surfaces.

3. There are a number of types of higher order cross planar features present. Should they be separated as S_3, S_4, etc., or should they be lumped into a single class as S_3 or should the term not be used here despite the fact that it fits the definition?

4. Some may wish to debate this.

IV. Tectonic significance.

A. It is obvious that in late and in post fold time there was strong shearing perpendicular to the fold axes.

1. This shear was dominated by strike slip displacement.

2. However, the sense of shear seems to have been reversible here.

B. These zones are a form of incipient ac jointing (perpendicular to the fold axes). The general problem of the stress field for ac jointing still remains but these particular "joints" are certainly the result of late stage shear in that ac plane.

C. Higher order S surfaces occur at many places in the Piedmont and have many orientations other than the ac plane. Many of these planes are much more consistent in their orientation and sense of shear than the structures observed here. They probably record some very interesting chapters of stress fields during the closing stages of deformation and by their transitional nature into jointing may shed some light on the stress fields responsible for these joints. Unfortunately, almost nothing is known of the regional nature of these higher order S surfaces. The problem stands begging for someone to work on it.

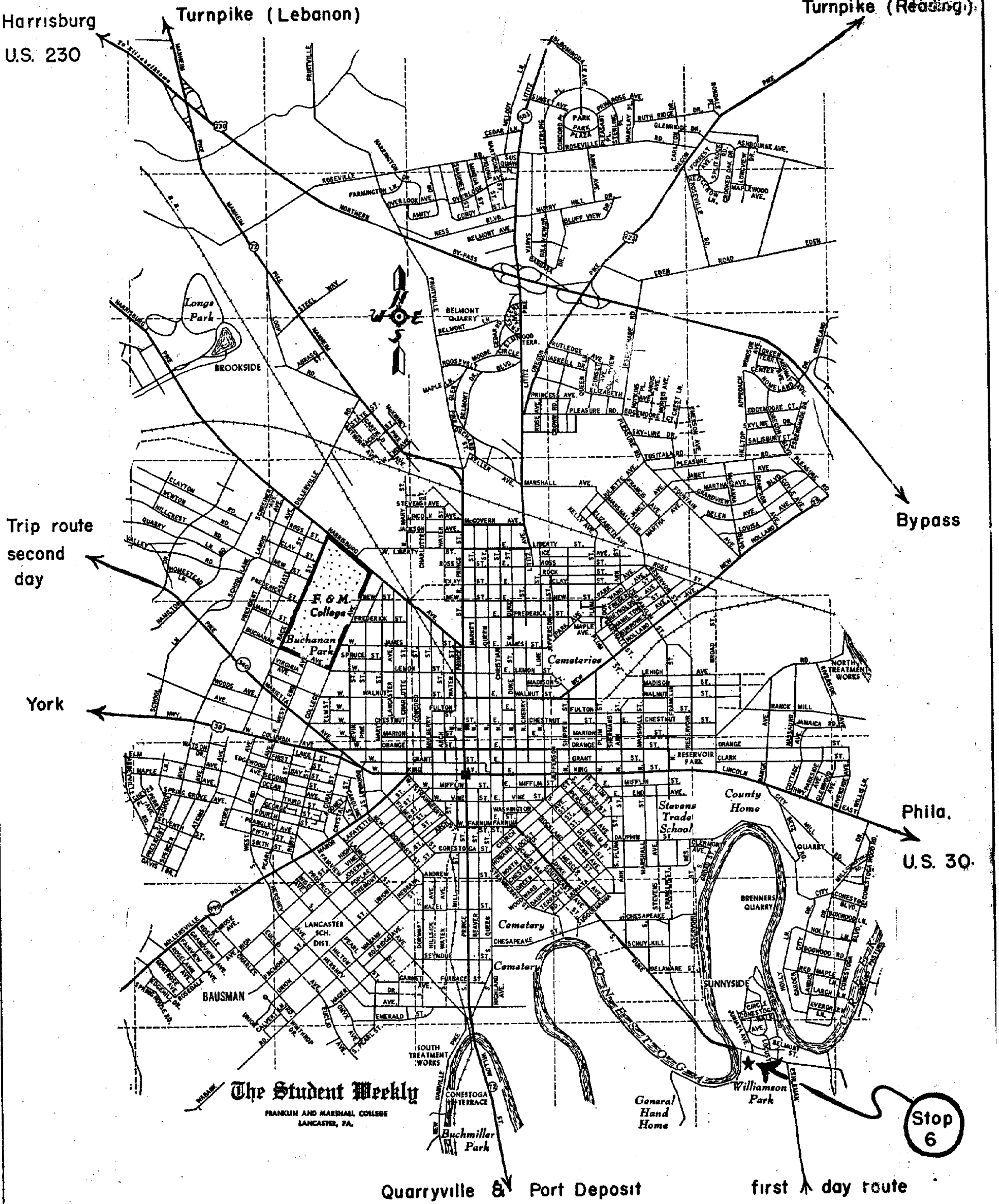


FIGURE II

CITY OF LANCASTER

Williamson's Park
(Continued)

V. Geomorphology.

A. The Conestoga River shows an amazing pattern of meanders arranged asymmetrically to its general course.

1. The long axes of these "hairpin" meanders all trend about N20W. The meanders have an extreme amplitude to wave length ratio.

2. This elongation is the same direction as the higher order S surfaces.

B. It is interesting to speculate whether these S surfaces could have controlled the meander development much as Hack and Young (1959) have suggested the Shenandoah meanders were controlled by cross joints (U.S.G.S. Prof. Paper 354-A).

C. On the other hand this direction is also perpendicular to the tight fold axes of the Conestoga limestone. It seems just as likely that the river would be forced to make its riffles perpendicular to these irregularities in its bed and hence emphasize this direction in its meander pattern as it entrenched its course.

D. The problem seems interesting but a coin should be tossed to see whether the structure men or the geomorphologists undertake it.

STOP 7. OYSTER POINT QUARRY

Donald U. Wise
Franklin and Marshall College

I. Introduction.

A. Location.

1. On the north flank of the Chickies Ridge Anticline 5.5 miles west of Lancaster.

2. This anticline of Cambrian quartzite plunges eastward and disappears beneath the Cambro-Ordovician limestones 2 miles to the east of this location.

3. Northward, the lowland is underlain by complexly folded and faulted Cambro-Ordovician limestones.

   (a) The slightly higher land in the middle distance is the Ordovician Cocalico shale, at least in part equivalent to the Martinsburg shale.

   (b) Skyline to the north is the Furnace Hills, composed of Triassic sediments and Triassic diabase intrusions.

B. Purpose of this stop.

1. Consider some of the internal adjustments undergone in quartzite deformation.

2. Presence of "worm tubes" permits the amount of deformation to be seen most readily.

3. Particular emphasis on the mechanism by which plunge was created in these folds.

II. Lithology.

A. Cambrian Chickies quartzite.

1. A well washed orthoquartzite, locally crossbedded.

2. Some former muddy layers are now phyllites.

3. A former beach sand.

4. Part of the basal Cambrian clastics which rest unconformably on basement to the north and east. Metavolcanics are present beneath these clastics in the core of this anticline 10 miles to the west.

Oyster Point Quarry
(Continued)

B. Quartzite is again weathering to sand; the material for which the quarry was worked.

1. A coarser grained bed on the top of the SE wall was more resistant to weathering and formed the economic limit to operation in that direction.

C. Quartz veins and pods.

1. Common, especially along the phyllite beds and in some places parallel to cleavage.

2. Some tourmaline associated with the quartz.

D. Scolithus tubes.

1. Are common throughout the well-washed units of the Chickies quartzite.

2. Particularly numerous here, accentuated by weathering.

3. Thought to be caused by worms rearranging the close packing of the sand in the ancient beach.

4. In less deformed areas the tubes are parallel, cylindrical, and perpendicular to bedding.

III. Structures.

A. Bedding is about N45E, 35° to SE.

1. Cleavage is N85W with vertical or steep south dip.

2. Cleavage-bedding intersection plunges eastward at 30 to 35 degrees reflecting the overall plunge of the fold axis of the major anticlinal structure.

B. Cleavage.

1. Throughout the quarry Scolithus tubes lie in the plane of the cleavage.

2. Means that the present cleavage represents planes that were originally perpendicular to bedding.

(a) Scolithus may have been the weaknesses that controlled the original fractures which eventually became cleavage.

(b) In a few places cleavage can be seen to undulate around the Scolithus, indicating some fracture control.

Oyster Point Quarry
(Continued)

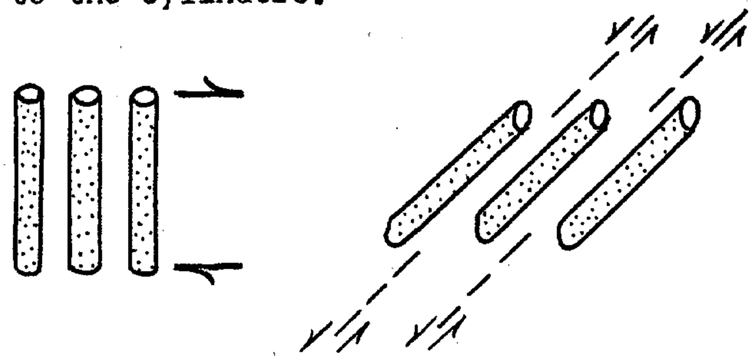
3. Flattening of Scolithus tubes in the plane of cleavage is the general rule here.

   (a) Original cylinders transformed into elliptical cross sections.

   (b) Scolithus now at 60 to 70 degree angle to bedding.

   (c) The cylinders must maintain essentially constant volume and at one place on Chickies Rock can be seen to maintain a constant length through a tight fold.

4. To permit this rotation of Scolithus from the perpendicular to bedding, considerable differential shear must take place parallel to the cylinders.



C. Plunge of folds.

1. Despite the Scolithus rotation in a north-south plane along with cleavage THE SCOLITHUS TUBES SHOW NO EVIDENCE OF EAST-WEST ROTATION IN ACCORD WITH THE EASTWARD PLUNGE OF THE FOLDS AT 30-35 DEGREES.

   (a) Similar relationships are present all along Chickies Ridge, even in smaller folds with reversed plunge.

2. As we look at a fold axis the Scolithus appear to be rotated with respect to it, but in reality the axis has been rotated with respect to the Scolithus which maintained essentially constant direction.

IV. Conclusions.

A. There has been shear movement in the plane of cleavage.

B. The movement seems to have been parallel to the dip of the cleavage and to the Scolithus tubes which lie in it.

Oyster Point Quarry
(Continued)

C. Where upward movement was greatest, pitch culminations were created.

1. The differential upward movement rotated the fold axes to produce the plunge.

2. This means that there has been shear parallel to the Scolithus in the ac plane (plane roughly perpendicular to the fold axis).

D. THE PLUNGE HERE SHOULD NOT BE THOUGHT OF AS A SIMPLE TILTING OF A BLOCK OF THE EARTH'S CRUST, BUT RATHER AS A CONSEQUENCE OF DIFFERENTIAL FLOW IN A MOVING MASS.

E. THE OVERALL EFFECT HAS BEEN ROTATION, NOT AROUND THE PLUNGING FOLD AXIS AS MIGHT BE EXPECTED, BUT RATHER AROUND A HORIZONTAL LINE, THE LINE OF STRIKE OF THAT AXIS.

STOP 8. CHICKIES ROCK

Donald U. Wise
Franklin and Marshall College

I. Introduction

A. The Rock itself is part of the cut made through a resistant quartzite ridge by the Susquehanna River and subsequently modified by the Pennsylvania Railroad to provide space for its roadbed.

1. A second cut, 175 feet deep and parallel to the river exposures, has been made for a new highway one-quarter mile to the east.

B. Chickies Rock is type locality for the Chickies quartzite.

1. This is the oldest "Cambrian" formation in the region.

2. Is a white vitreous quartzite, commonly crossbedded, showing some "worm borings" and interlayered with differing percentages of phyllitic material.

   (a) The "Cambrian" age is by courtesy in that it has yielded no Cambrian fossils but is conformably below formations which have yielded such fossils.

   (b) The basal member of the Chickies quartzite is the Hallam conglomerate, named for the town of Hallam several miles to the southwest.

3. East of this region the Chickies quartzite rests unconformably on the basement of the Baltimore gneiss.

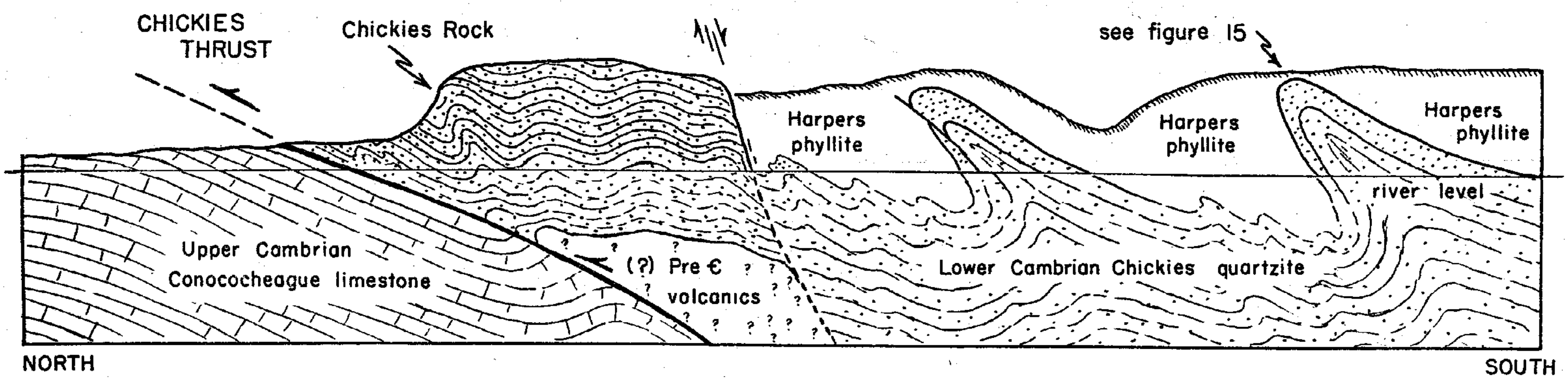
4. Westward it overlies volcanic rocks (metabasalts and aporhyolites) generally similar to the rock types exposed in the northern tip of the Blue Ridge.

   (a) These volcanics are exposed beneath the Chickies quartzite 2 miles west of Chickies Rock along the same anticlinal structure.

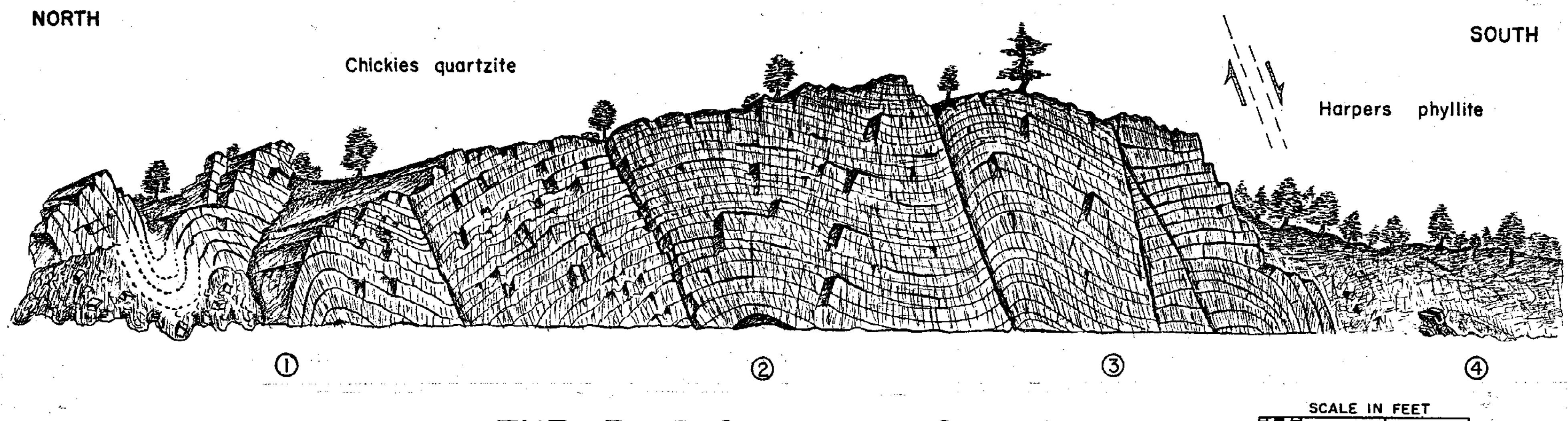
C. Chickies Rock is also the type locality for *Scolithus linearis*, a problematical fossil.

1. These are cylindrical tubes up to several feet long, occurring in great numbers perpendicular to bedding (where undeformed). They are most common in the clean well washed sands.

2. Originally described by the old ironmaster, Colonel Haldeman whose mansion stood at the north end of Chickies Rock. The spring and some of the foundations are still visible today.



SKETCH OF THE CHICKIES RIDGE FOLD AND THRUST ZONE AS EXPOSED IN THE BLUFFS OF THE SUSQUEHANNA RIVER



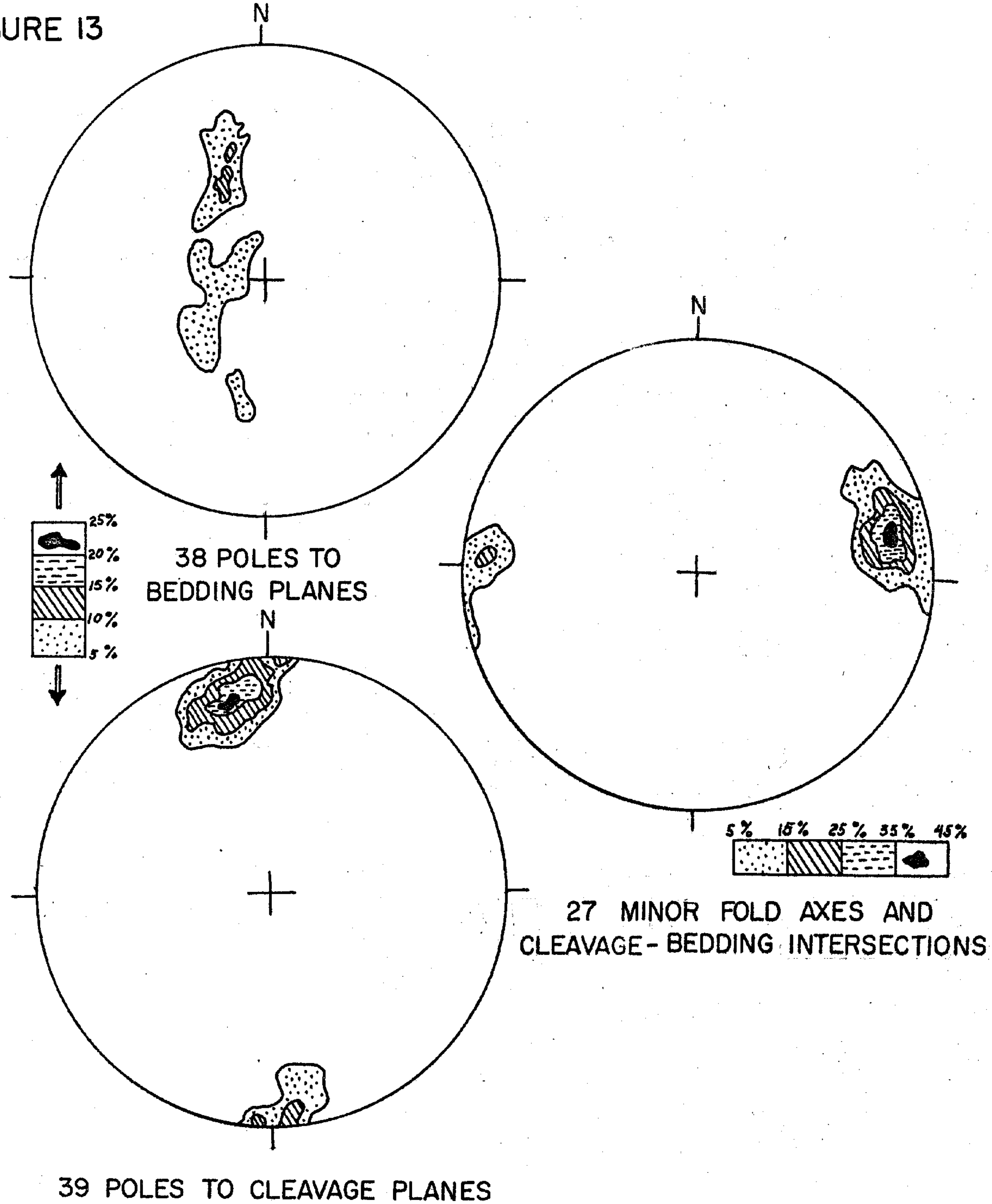
ocation: along the Susquehanna River, Lancaster County, Pennsylvania

THE FACE OF CHICKIES ROCK

1951
By D. U. Wise

FIGURE 12

FIGURE 13



LOWER HEMISPHERE EQUAL AREA PLOTS

CHICKIES ROCK, COLUMBIA, PENNSYLVANIA

Chickies Rock
(Continued)

II. General Structure of the area.

A. Chickies Ridge is a complex anticlinal structure.

1. The structure strikes N80E and plunges 10-15°E.

2. Field trip passed the plunging nose near Rohrerstown 10 miles to the east.

B. The Ridge is asymmetric with thrusting along its northern boundary and northward overturn of the lesser structures within it.

1. On its south flank the full stratigraphy is present.

2. On the north flank the Chickies quartzite (lowermost "Cambrian") is adjacent to Conococheague limestone (uppermost Cambrian).

3. This is a stratigraphic throw of about 5000 feet.

4. Jonas and Stose interpreted this as the Chickies thrust, part of the same general zone including the Stoner thrust and their "Martic thrust" a few miles to the south.

C. In the Susquehanna River bluffs three lesser upfolds of Chickies quartzite appear in the ridge and are separated by depressed zones of the overlying Harpers phyllite.

1. Southern most anticline -- (illustrated in the photograph, figure 15).

(a) Overturned but not broken.

(b) The same structure appears to the east in the middle highway cut where it has become a break thrust.

2. Middle anticline.

(a) Exposed in the abandoned quarry 200 yards south of Chickies Rock where it is a complex break thrust.

(b) Along strike it becomes a beautiful overturned fold (with some slippage on its overturned limb) in the southern part of the northern most roadcut.

Chickies Rock
(Continued)

3. Chickies Rock -- the third "anticline".

   (a) Generally anticlinal.

   (b) Part of the same structure appears in the northernmost end of the northern roadcut.

4. Projection of these structures from the river bluffs to the road cuts is a bit confusing without the use of maps because in this local area the northern escarpment of Chickies Ridge does not parallel the fold axes.

D. Complexity of the folding.

1. Is best indicated by the exposures of quartzite which are visible in the riverbed at low water.

2. See photography, figure 14.

3. This reveals many plunging folds, some of them broken by faulting. SOME MINOR FOLDS PLUNGE EAST, ADJACENT ONES MAY PLUNGE WEST.

4. Considering that this is a quartzite the amount of flowage and folding is surprising.

E. Attitude of the "thrust".

1. The frontal fault of Chickies Ridge can be located at low water in the Susquehanna to within about 100 yards.

2. The Conococheague limestone dips southward, apparently beneath the Ridge, at a consistent angle of about 20-30 degrees.

   (a) Outcrops can be seen at the foot of the abutments of the small railroad bridge 200 yards north of Chickies Rock, at the mouth of Chickies Creek, or in the large quarries just northeast of the parking area for this stop.

3. The massive quartzites of the Chickies formation dip southward at similar angles adjacent to the contact.

4. It seems quite likely that the thrust is here a bedding plane feature sliding a sheet of the Cambrian quartzites out over the adjacent limestones.

   (a) If true, the thrust would have about the same 20 to 30 degree dip.

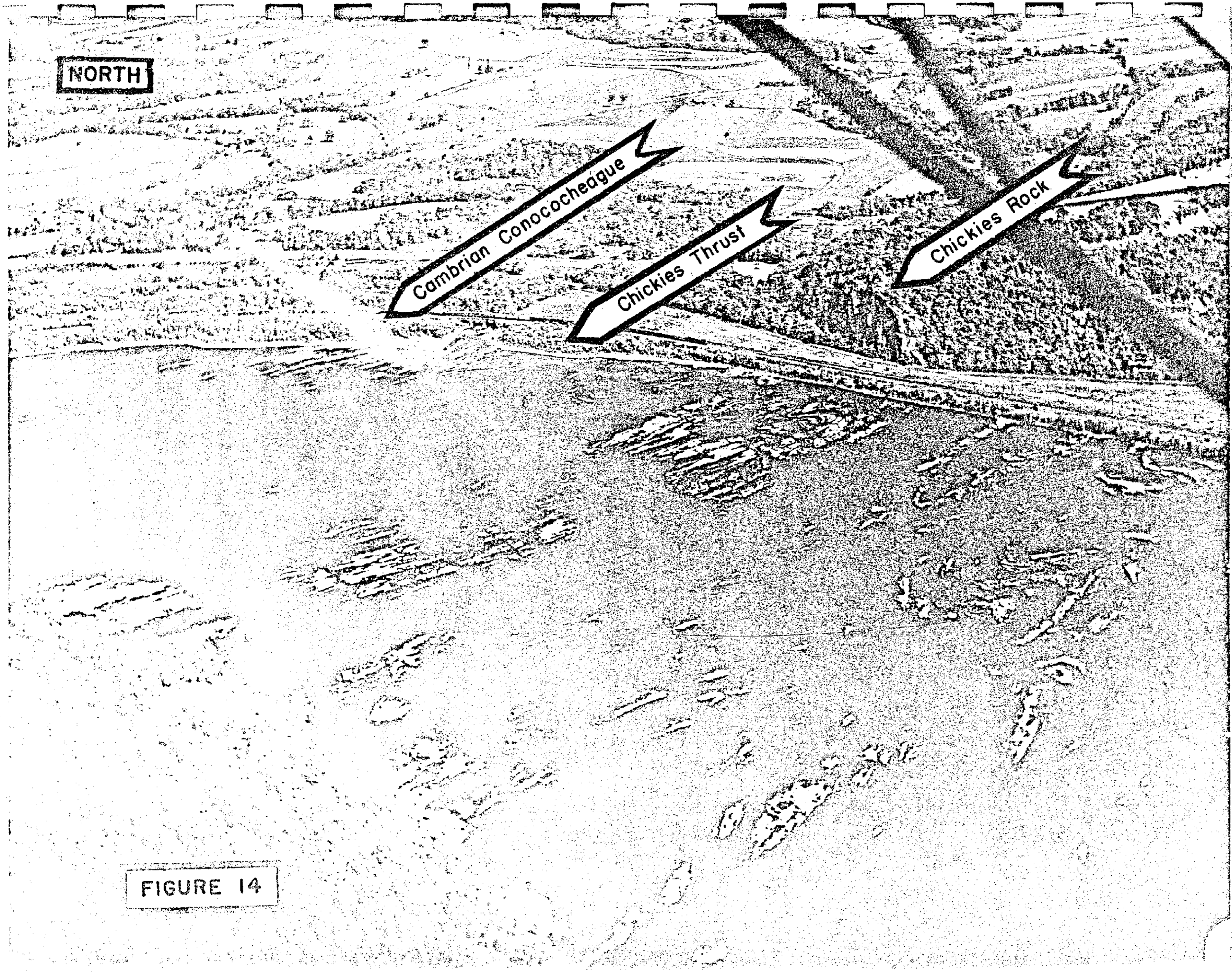

NORTH
Cambrian Conococheague
Chickies Thrust
Chickies Rock

FIGURE 14

Chickies Rock
(Continued)

III. Detailed structures on the face of Chickies Rock.

A. The face shows many small scale features of bedding, cleavage, types, flexural slippage, lineation types, and fold mechanics.

1. Many of the structural mechanisms can be seen more clearly because of the presence of the primary Scolithus structures which provide a measure of the deformation.

2. These cannot all be discussed in detail. Many have been highlighted with paint on the outcrop.

3. The larger features of the outcrop and the locations may be found by reference to the pen and ink sketch of the face.

B. The suggested tour of the outcrop is from north to south following the marked route along the base of the cliff. The return route should circle out from the cliff to obtain a full view of its face.

C. Location 1 (see sketch of face).

1. Problem is first to find bedding (curves from the vertical upwards and to the south through a fairly tight fold.)

2. Cleavage fans the fold in the manner commonly ascribed to fracture cleavage.

3. On the left (north) side of the crop the lines of bedding-cleavage intersection correctly indicate the eastward plunge of the structure.

(a) Here, the bedding surface is roughened by tiny displacements along each of the cleavage packets--a characteristic sometimes ascribed to slip folding and slip cleavage.

4. Curvature of some cleavage surfaces near the bedding surfaces appears to be drag by flexural slip along the bedding planes.

5. Fifteen feet higher, along the north side of the crop are ripple marks on the bedding surface--a primary lineation in the midst of a host of secondary lineations.

(a) The ripples show secondary roughening by slight slippage along the cleavage surfaces.

Chickies Rock
(Continued)

D. Location 2.

1. A small "walk in" anticline shows one of the small plunging folds similar to those seen in the river at low water, as well as fanning of cleavage.

E. Location 3.

1. Steeply dipping cleavage in quartzites, moderately dipping in the phyllite.

2. Features such as this are commonly considered the result of refraction of the fractures as they pass through differing rock types.

3. An alternative to refraction of cleavage is to consider these as two different types of cleavage.

   (a) Much of the cleavage in the phyllite has formed under the influence of flexural slip between competent horizons.

   (b) In some areas of Chickies Rock the cleavage does curve from the quartzite into the phyllite. However, Scolithus are present in the quartzite in some of these areas, curving with the cleavage. The conclusion is that the cleavage was once planar with the Scolithus lying in it and subsequently both cleavage and Scolithus were deformed by continuing flexural slip.

   (c) Were it not for the Scolithus this would probably be interpreted, incorrectly, as "simple refraction of cleavage." It is interesting to speculate how many other "cleavage refractions" may be of this polygenetic origin.

4. Just to the south are small displacements associated with a fault block. Some members may be interested in working out this problem.

F. Location 4 - small outcrop 75 feet south of the main Chickies Rock Face.

1. This hillslope is Harpers phyllite, the formation overlying the Chickies quartzite. It has been dropped at least 100 feet with respect to the outcrops just to the north.

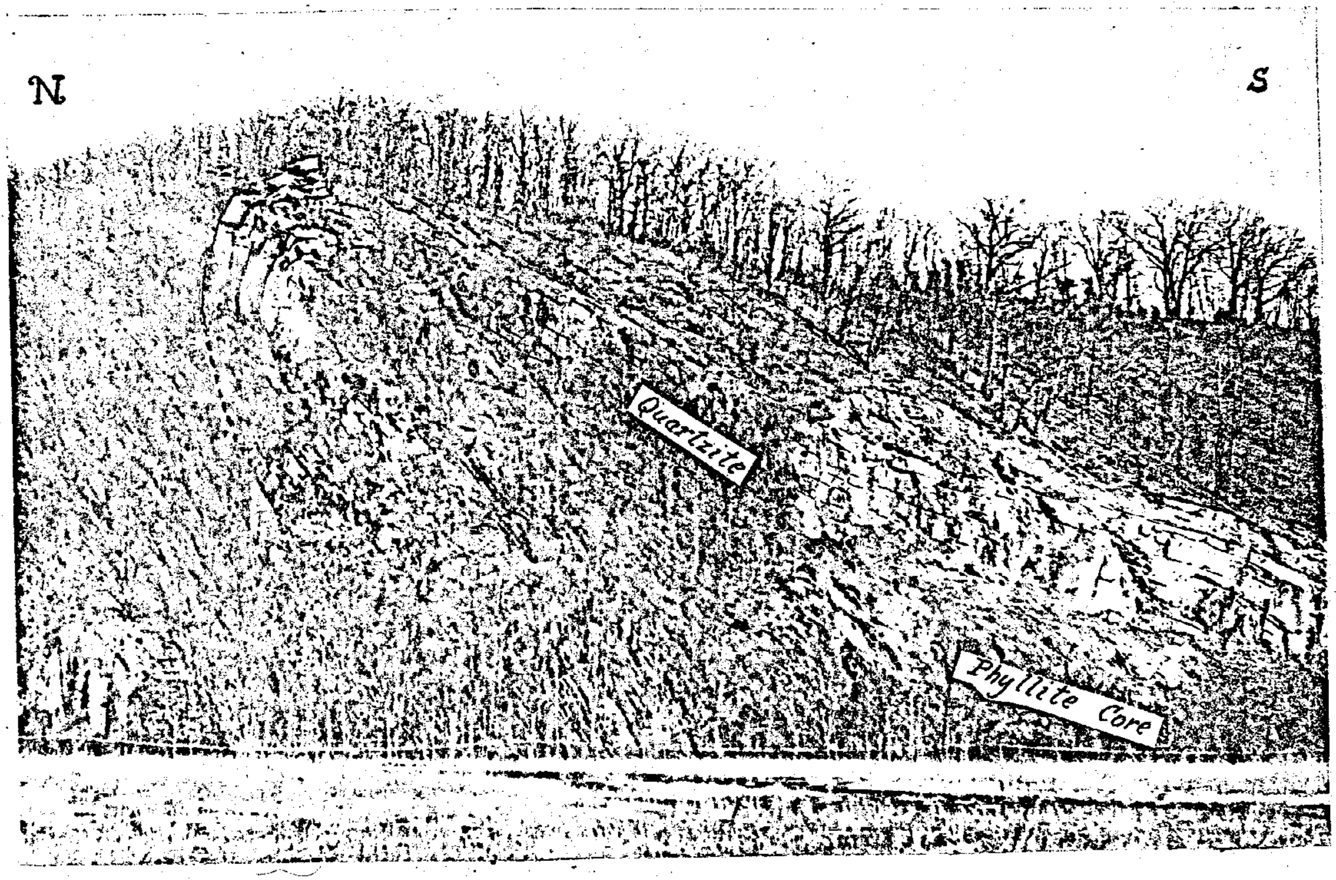


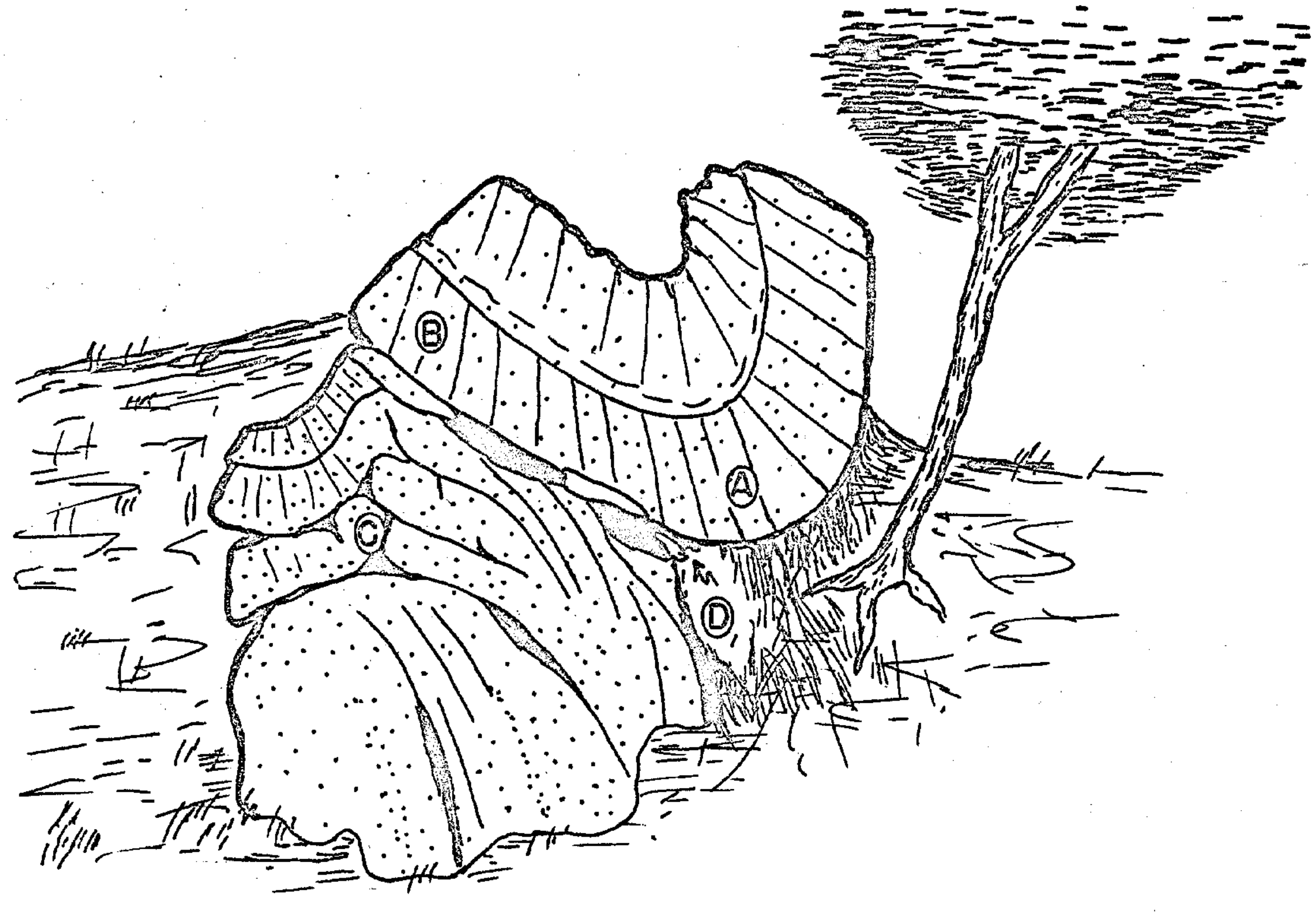
Figure 15. Overturned fold in the Chickies Quartzite one-half mile south of Chickies Rock. This is the southernmost fold shown on figure 12 (top). A phyllitic bed in the core aided in the formation of the tight fold.

Chickies Rock
(Continued)

(a) The small outcrop seems to be part of the transitional beds from the Chickies to the Harpers.

(b) Although the massive quartzites in the face of Chickies Rock fold down at the south end of the face, there is not sufficient room for the massive quartzites to pass between the small outcrop and the end of the main face. A fault or fault zone is indicated.

(c) Several smaller faults of this zone can be seen on the upper parts of the south end of the rock. (It would be advisable not to climb to them because of the danger of rocks or bodies falling on the people below.) These minor faults appear to be a compromise between cleavage surfaces and phyllitic bedding surfaces, curving sharply from one to the other but maintaining an average dip of about 70° to the south. Movement on some of these curving faults has tended to smooth the fault plane as indicated by curvature of some of the cleavage surfaces and associated Scolithus tubes.



Chickies Rock
(Continued)

2. This small outcrop is sketched (previous page) and a number of locations designated by letter on the figure.

   (a) Location A - note Scolithus tubes flattened in the plane of cleavage. THE SCOLITHUS LIE IN A VERTICAL NORTH-SOUTH PLANE AND DO NOT ENTER INTO THE EASTWARD PLUNGE OF THE FOLD.

   (b) Location B - this bed appears to change thickness across the fold. In an effort to learn how stretching or flowage in the bed took place, a series of measurements were taken of the distance from the top to the bottom of the bed parallel to the Scolithus and the associated fanning cleavage. The surprising result was that in this bed THE SCOLITHUS MAINTAIN A CONSTANT LENGTH despite tight folding and apparent thickness changes of the bed. This length is most likely the original or true thickness of the bed. It would appear that here the Scolithus may have been flattened in the plane of cleavage but they were not elongated in that plane. The crest of the fold, rather than being thickened, exhibits the true thickness of the bed and it is the limb which in reality has been thinned by internal rotation resulting from differential movement of the top with respect to the bottom of the bed.

   If the limbs of this fold have been thinned then the bed itself must have been elongated in order to maintain approximately constant volume. Elongation of beds in the compressive environment of thrusting at first seems to be inconsistent. When one recalls the stretching of the overturned limb so common in break thrusting, the idea seems more reasonable. This factor of elongation is commonly overlooked in calculation of the amount of "shortening" accomplished by a thrust. Indeed, the separation of true crustal shortening from mere crumpling with elongation of beds is one of the important tectonic problems in this part of the Piedmont.

   (c) Location C - The quartzites have parted at the fold crests and the phyllites show intrusive relations into the openings. Some phyllites merge with others so the correlation of quartzite beds across the fold is uncertain.

   (d) Location D - Quartz pods are along the phyllitic units. The phyllites indicate extensive flexural slip.

Chickies Rock
(Continued)

IV. Macro-petrofabrics

A. Illustrated on figure 13.

B. The Macro-petrofabrics provide a statistical picture supporting the visible structural picture at Chickies Rock.

C. Poles to bedding planes.

1. Form a girdle in a north-south plane dipping steeply to the west.

2. This girdle is perpendicular to the maximum for fold axis lineations.

D. Poles to cleavage planes show both north and south dips indicating some fanning of cleavage across the fold.

1. The average of this fanning cleavage is a steeply south dipping plane.

2. The south dip reflects the general overturning of axial planes of folds toward the north.

E. Fold axis lineations and cleavage-bedding intersections:

1. Show the N80E strike of Chickies Ridge and have a maximum indicating the eastward plunge.

2. Also show a few of the reversed westward plunges of folds.

STOP 9. RHEEMS QUARRY

Donald U. Wise
Franklin and Marshall College

I. Location and General Setting.

A. West end of Rheems, Pennsylvania, 3 miles east of Elizabethtown.

1. Owned and operated by the Heisey Brothers of Rheems.

B. Part of a broad area of Cambro-Ordovician carbonates lying north of the quartzite fold and thrust structures of Chickies Ridge.

1. A belt of Triassic sediments and intrusions separates this carbonate belt from the Great Valley proper to the north.

(a) 300 yards north of this quarry is the unconformable contact of the south edge of the Triassic sediments over the carbonates.

2. This carbonate belt in which we stand is quite similar in structure and lithology to parts of the Great Valley to the north.

(a) Nappe structure and recumbent folding are known to occur in the Great Valley (Gray, Geyer, et al, 1958) and will be discussed at stop 11.

(b) Similar features are present in the area 6 to 12 miles north of Lancaster where many square miles of the carbonates are known to be overturned (work in progress at Franklin and Marshall College).

C. This quarry seems to be part of an area of extensive horizontal transport of carbonate rocks from south to north.

1. Part of the Ordovician Beekmantown limestone.

2. Fold axes trend generally ENE to E.

3. Detailed mapping in the areas surrounding the quarry has not been undertaken so its exact relationship to the fold and thrust picture is unknown.

D. Reason for stopping here is

1. To illustrate some of the mechanics of internal adjustments to movement in a flowing limestone and dolomite mass.

2. The more general tectonic problems of the nappes will be discussed at stop 11.

3. For our discussion here, we need only remember that this is part of a much larger carbonate mass in which tectonic transport was from south to north.

II. Overall structure of the quarry.

A. The intensely folded structures on the east wall of the quarry are in striking contrast to the uniformly dipping structures on the west wall.

1. This can be seen in figure 16.

2. The upper part of the figure is the east wall.

(a) The present new entrance to the quarry is through this face one-third of the way from the left hand edge of the figure.

3. Lower part of the figure is the MIRROR IMAGE of the west wall (reversed so it can appear in the same illustration).

B. Fold structures plunge eastward at 5 to 15 degrees as can be seen best on the north wall.

1. This means that the east wall is structurally higher than the west.

(a) By means of alidade mapping and projection of fold axes and axial planes all visible or once visible structures were combined into figure 16 , a cross section at right angles to the fold axes.

2. The structural relationship of the east and west walls is obvious in the figure.

C. Upper part of the northeast corner of the quarry is a folded bedding surface (a syncline as will be discussed later).

1. THE AXIAL PLANE OF THIS SYNCLINE CAN BE TRACED THE ENTIRE WIDTH OF THE QUARRY.

(a) On figure 16 the fold form can be seen just beneath the top erosion surface from one side of the figure to the other.

2. The anticline just beneath this fold can be traced in similar fashion from one side of the quarry to the other.

Rheems Quarry
(Continued)

3. These two planes retain a reasonably constant separation of 15 to 25 feet.

   (a) Perpendicular to the fold axes they rise in elevation only 35 feet across the 600 foot width of the quarry.

   (b) This is an average dip of 3°--not quite perfect recumbency!

D. In recumbent folds the terms anticline and syncline may be difficult to apply unless relative ages of beds or the direction of tectonic transport is known. No direct evidence of relative ages of beds nor of primary depositional top and bottom features has been found.

1. Anticlines ordinarily represent rock masses which are pushed up or out farther than the adjacent areas.

   (a) Synclines are the reverse--they are slightly retarded with respect to the overall movement of the mass.

2. Considering the regional south to north tectonic transport the topmost fold on the east face must be considered as retarded--a syncline, and the fold beneath it an anticline which has pushed a bit farther forward (to the north).

3. The entire west face is thus the overturned limb of a much larger fold.

4. This argument based only on assumed direction of transport is admittedly weak. However--

   (a) The same conclusions as to terminology and transport direction can be reached solely from the structural differences between right side up and upside down limbs visible in the quarry (Item IV, D).

E. THESE PLANES OF DIFFERENTIAL NORTH-SOUTH HORIZONTAL MOVEMENT ARE THE FUNDAMENTAL STRUCTURES PRESENT.

1. All other structures represent local adjustments, largely pressure driven, to the fundamental movements.

2. They might possibly be considered as planes of laminar viscous flow on a gigantic scale.

3. Because each lamination is advanced or retarded about the same amount at each place the overall pattern is an approximation to <u>similar folding</u> and the fold form, though small in amplitude can be traced for long distances along the axial planes.

Rheems Quarry
(Continued)

III. Yield character and rock type.

A. Some of the carbonate beds show extreme flowage particularly into the crests of folds.

1. Others show relatively brittle behavior, producing calcite filled extension breccias and generally retaining the same thickness through the limbs and crests of folds.

2. Insoluble residue analysis of six specimens each, of brittle and of flowed carbonate, showed no systematic differences in the percent insoluble residue.

3. The beds with strong flowage are all calcitic.

(a) The brittle beds are all dolomitic.

B. Many of the interesting small scale structures are the result of local pressure differences created by differential yield of these two interbedded rock types.

IV. Smaller scale features.

A. Thickening of fold crests.

1. Similar folding of beds of constant thickness results in open spaces in the crests.

(a) In the flow environment these incipient crestal open spaces are zones of lower pressure than on the adjacent limbs.

(b) Thus a pressure difference is created which pumps the less viscous calcite beds into the fold crests to thicken them.

2. Best examples of this crestal thickening are in the center and at the left end of the east face.

(a) One bed is 4 feet thick on the limbs and 14 feet thick on the crest.

(b) Examples of poorly developed cleavage in limestone can be seen in the crests of these same folds.

3. This is a local flowage in a direction other than the overall horizontal movement.

Rheems Quarry
(Continued)

B. Bedding plane slickensides.

1. Similar folding necessitates differential slip between adjacent beds.

2. Evidences of this slip are common throughout the quarry.

3. Best shown on north wall at right (east) end.

C. Boudinage.

1. There are at least 20 examples of well-developed boudinage structure.

   (a) All on the overturned limb in the west wall.

   (b) Not a single boudin on the vertical and right-side-up beds of the east wall.

2. The boudinage reflect the intense stretching in the overturned limb.

   (a) Forward movement of an overriding mass simply stretches and tears apart the overturned limb beneath it.

   (b) Cloos found this in his oolites and it is also known from many of the recumbent folds in the Alps.

3. The limestones flowed as stretching continued; the more brittle dolomites necked down into boudins or parted to permit calcite veining.

   (a) Best seen in the left (south) portion of the west wall.

4. The separation of a dolomite bed into boudinage created a low pressure zone between the boudinage masses.

   (a) Pressure difference essentially "sucks" the adjacent limestones into the open space to create an "Hourglass fold".

   (b) The part of the low pressure zone not eliminated by "Hourglass folding" is eliminated by Riecke's principle of deposition from solution at the points of low pressure. The evidence for this is the great concentration of calcite veins in the low pressure necks between boudins.

Rheems Quarry
(Continued)

(c) The pressure differences of stretching and "Hour-glass folding" in one bed probably affected boudinage formation in adjacent beds as evidenced by a crude enechelon spacing of boudins to fill the space vacated by an adjacent "Hour glass".

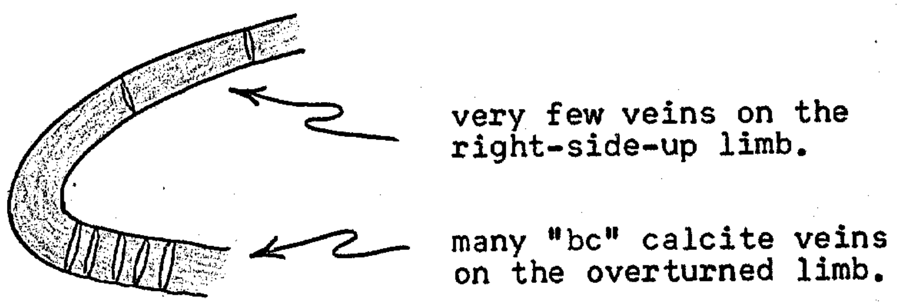
D. Jointing and veining.

1. The joint sets which opened at the time of folding were low pressure zones which would be filled with calcite according to Riecke's principle.

2. On the overturned limb where great stretching took place, the veins are dominantly in the "b-c" direction, parallel to the fold axes and perpendicular to the direction of elongation.

   (a) Locally the veins are so closely spaced that a calcite filled extension breccia has been produced. (Specimens can be collected at the center of the west wall.)

3. The distinction in stretching and veining between overturned and non-overturned limbs can best be seen in the anticline on either side of the quarry entrance.



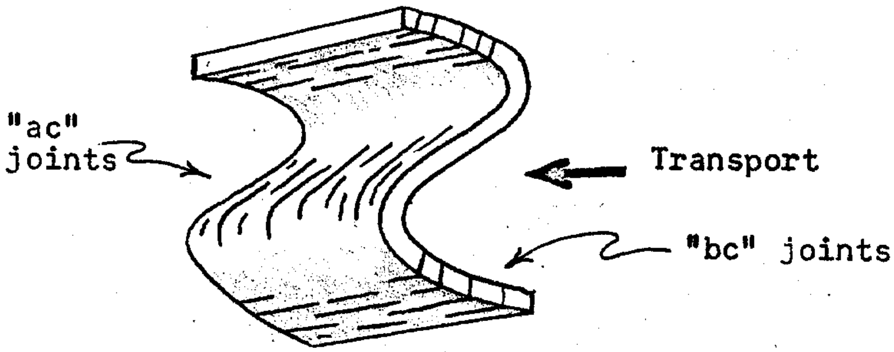
   (a) If it is admitted that overturned limbs are more intensely stretched, then this difference in veining distinquishes that overturned limb, indicates the anticline from the syncline and supports the assumed direction of regional tectonic transport from south to north.

4. The right-side-up limbs are not stretched in the same way but appear to be zones in which maximum extension was parallel to the fold axes. Here calcite veins in the "ac" plane (perpendicular to fold axes) seem to be the rule.

Rheems Quarry
(Continued)

(a) Best seen in the south wall of the quarry entrance.

5. Thus, the calcite veins show that two distinct stress environments operated in different fashions on the limbs of the same fold--"ac" extension jointing on the right-side-up limb, "bc" extension jointing on the upside down limb.



E. Feldspar

1. Some of the veins and joints contain some pink feldspar.

2. This is most common in the NE corner of the quarry where it is best developed in the "ac" joint sets.

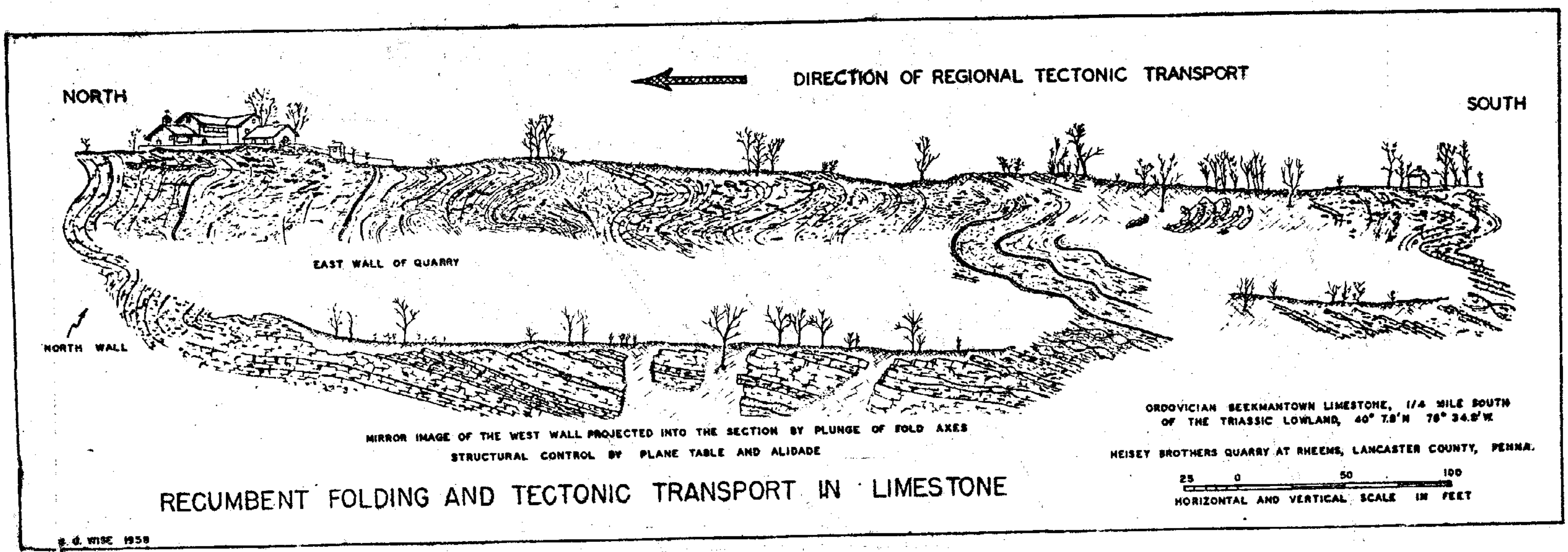
V. Summary.

A. The primary deformation pattern here is one of differential movement along essentially horizontal planes through a mass behaving in a generally viscous manner. Fluid méchanical principles would suggest that planar zones moving forward more rapidly to form anticlines are the zones of slightly higher pressures.

B. The overall flow pattern creates many smaller scale pressure differences, particularly by differential yiéld of the several rock types.

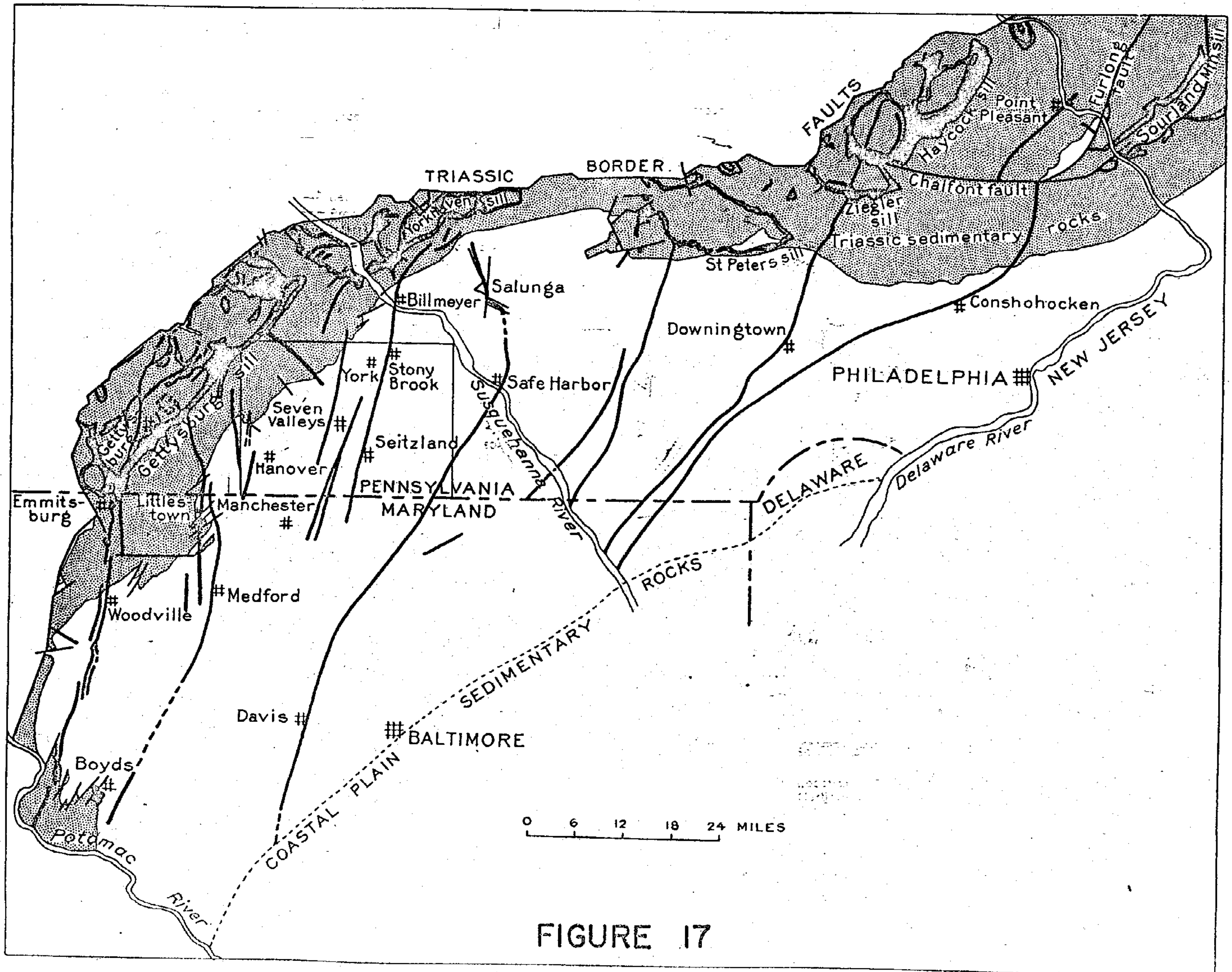
1. These local pressure differences drive local rock flowage in many directions with little relation to the primary flow pattern.

2. They also drive considerable solution and redeposition of calcite.



DIRECTION OF REGIONAL TECTONIC TRANSPORT
NORTH
SOUTH
EAST WALL OF QUARRY
NORTH WALL
MIRROR IMAGE OF THE WEST WALL PROJECTED INTO THE SECTION BY PLUNGE OF FOLD AXES
STRUCTURAL CONTROL BY PLANE TABLE AND ALIDADE
ORDOVICIAN BEEKMANTOWN LIMESTONE, 1/4 MILE SOUTH OF THE TRIASSIC LOWLAND, 40° 7.8'N 76° 34.8'W
HEISEY BROTHERS QUARRY AT RHEEMS, LANCASTER COUNTY, PENNA.
25 0 50 100
HORIZONTAL AND VERTICAL SCALE IN FEET
RECUMBENT FOLDING AND TECTONIC TRANSPORT IN LIMESTONE
D. U. WISE 1958

figure 16



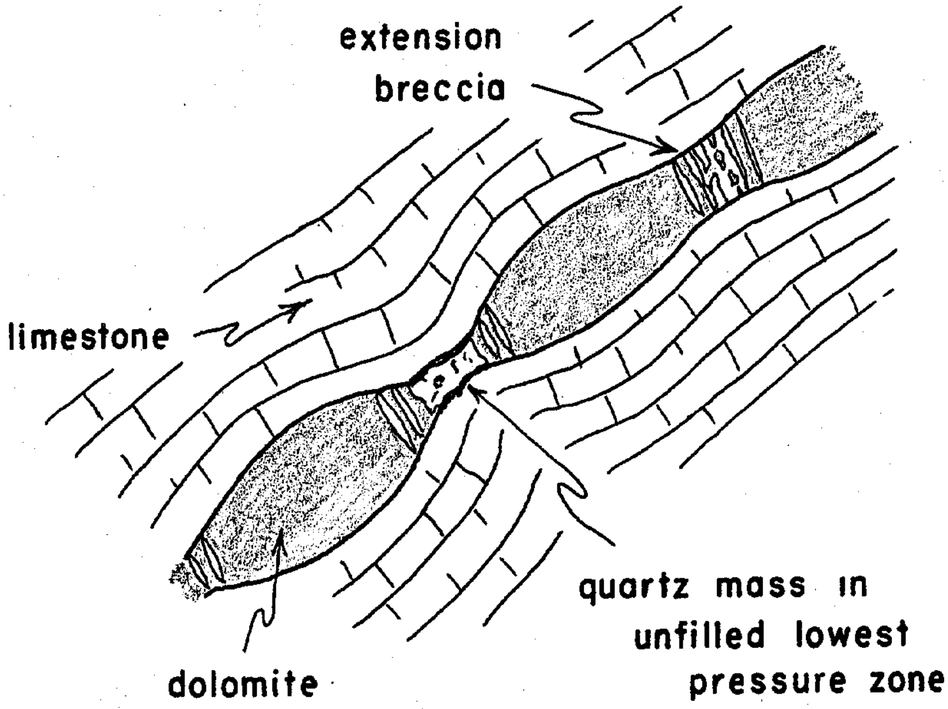
SKETCH MAP OF TRIASSIC SEDIMENTARY ROCKS IN WESTERN NEW JERSEY, PENNSYLVANIA, AND MARYLAND, SHOWING DIABASE SILLS, CROSS-CUTTING BODIES, AND DIKES.

Dotted areas, Triassic sedimentary rocks; solid black areas and heavy black lines, Triassic diabase; and lighter black lines, faults. The Gettysburg sill crosses the northwest corner of the Hanover quadrangle. Hanover-York district shown by rectangle.

Rheems Quarry
(Continued)

C. The reasons for the local pressure differences here seem reasonably clear but the underlying causes of the pressure distributions driving the horizontally moving sheets of viscous material is one of the many unsolved tectonic problems of the region.

D. Calcite petrofabric work on these different movements needs to be done, but no brave soul has undertaken it as yet.



"HOURGLASS FOLDING" INTO THE LOW PRESSURE ZONE BETWEEN BOUDINAGE

STOP 10
NOTES ON THE NEW OXFORD FORMATION AND THE LIMESTONE CONGLOMERATE AT CONOY CREEK

Dean B. McLaughlin
Pennsylvania Geological Survey
and University of Michigan

The New Oxford formation is the lowest member of the Newark Group of Upper Triassic age. It overlies the Paleozoic rocks with marked unconformity. No actual contact between the Paleozoic rocks is exposed in western Lancaster County, so far as the writer is aware, but the unconformable relations are well shown by the map distribution of the formations, which shows the base of the Triassic bevelling the folded Paleozoics. A large angular unconformity is rather obvious in the discordant dips of the beds exposed along U.S. 230 near Rheems, southeast of Elizabethtown. There the Ordovician limestone dips southerly, about 30°, while the New Oxford arkoses nearby dip northwesterly about 30°.

The best exposures of the New Oxford formation in Lancaster County are those in the cuts of the Pennsylvania Railroad southeast of the Elizabethtown station. The rocks there in the lower part of the formation are almost entirely arkoses, ranging from very coarse to fine-grained, with some beds of quartz-pebble conglomerate, minor interbedded shales, and a few beds of impure nodular limestone. The higher parts of the formation also consist mainly of arkose, but they contain a greater percentage of interbedded red, greenish, and gray shales, siltstones, and fine sandstone.

Along much of the basal contact of the Triassic, only minor conglomerates occur interbedded with the arkose, as at

Elizabethtown. In a few places conglomerates are strongly developed, but these usually have pebbles of vein quartz and Cambrian quartzite. Occurrences of limestone conglomerate at the base of the series are few, and for the most part small.

Near the Susquehanna River is a unique development of basal limestone conglomerate, as regards both lateral extend and thickness. This rock is well exposed in three localities:
(1) near Conoy Creek about 3 miles northeast of Bainbridge;
(2) in a small patch of woods one-half mile east of Bainbridge;
(3) along the freight line of the Pennsylvania Railroad on the west bank of the Susquehanna east of Mount Wolf.

The occurrence on Conoy Creek is the largest. Numerous good exposures are found in an area about 500 by 100 yards, with its long dimensions extending northeast to southwest along the strike. One very large practically continuous single exposure, which looks superficially like a roche moutonne, is more than 100 yards long.

The rock appears much like a breccia. The phenoclasts are mostly quite angular. Average dimensions are a few inches, but they range from small chips to boulders more than a foot in diameter. They are chaotically arranged and very densely packed, with only a little reddish or pinkish silty matrix filling the interstices between fragments each of which touches several others. The phenoclasts are of light gray, bluish gray, light yellowish, and sometimes pinkish limestone and dolomite, and were certainly derived from the immediately underlying Paleozoic carbonates

A rude stratification can be made out in almost any part of these exposures, though sometimes with difficulty. Tabular phenoclasts tend to lie parallel to the bedding, and indications can be seen of sorting, in that there is some alternation of thick bands with larger and smaller pebbles. In the southwestern part of the outcrop area a reddish silty interbed several inches thick is well developed. This contains numerous limestone pebbles, but they make up only about 30 percent of the rock, as against more than 90 percent for most of the outcrop. A few scattered small pebbles of vein quartz were seen. Several measurements give an average strike and dip N50°E, 35°NW.

North of the limestone conglomerate, more than 500 feet of arkose, with some interbedded quartz conglomerate and minor shales, are exposed along the road that parallels Conoy Creek. Dips are northwestward 25° on the main bedding, while crossbedding dips in the same direction about 40°. The streams that deposited the arkoses evidently flowed from the south or southeast.

One of the large diabase dikes (the one that causes the Haldeman Riffles in the Susquehanna) passes a few hundred yards east of the limestone conglomerate exposures. There are no indications of alteration.

The exposures near Bainbridge are large and similar in character to those at Conoy Creek, but bedding is a little more evident. There the rock has been quarried on a small scale, but the operation apparently has been abandoned. The average of measurements there gives strike N60°E, dip 32°NW.

The third exposure, on the west bank of the river, is small and is probably an outlying part of the Bainbridge mass. It is the lowest rock of the Triassic section, but is some 250 feet from the nearest outcrop of limestone. This occurrence is noteworthy because the limestone conglomerate is overlain (without exposed contact) by the greatest known development of quartz conglomerate near the base of the Triassic. The latter consists of densely packed, moderately rounded and subangular pebbles of vein quartz and white vitreous Chickies quartzite (Cambrian). The matrix is arkosic.

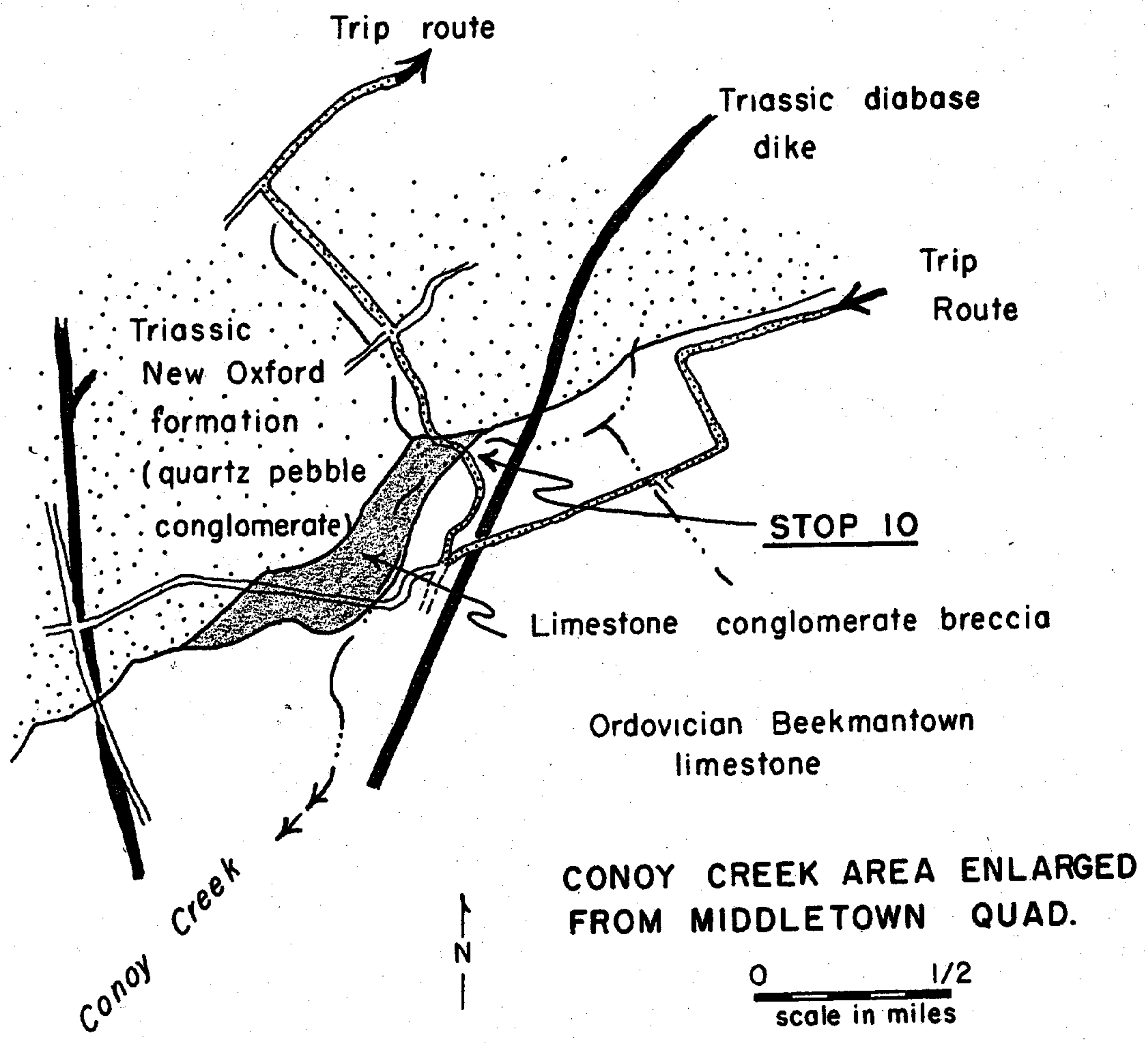
Both at Conoy Creek and at Bainbridge, the limestone conglomerate area coincides with a distinct cusp in the boundary between the Paleozoic and Triassic. The base of the overlying arkoses is a fairly straight strike line; the local limestone conglomerate projects into the limestone area to the southeast. This relationship suggests that both of these strong developments of limestone conglomerate represent accumulations of material washed into local valleys of the pre-Triassic surface. Local relief of the order of 200 feet is indicated.

The highly angular phenoclasts indicate transportation over only a very short distance, but the rock is clearly stratified, and is not simply a talus, nor is it composed of residual fragments in a soil. The dip is steeper than that of the overlying arkoses, and this may represent torrential bedding produced by deposition from a northwestward-flowing stream.

The absence of any mixture of limestone and quartz conglomerate further suggests a possibility that a considerable time elapsed between the deposition of the limestone conglomerate and of the overlying arkoses and quartz conglomerate. The latter also could have come only from the south, where Cambrian quartzite and feldspathic schists occur only a few miles away.

McLaughlin, D., 1958, Triassic north border near South Mountain; Proc. Penna. Academy of Sci., vol. 32, p. 151-155

Stose, G.W., and Jonas, A.I., 1933, Geology and mineral resources of the Middletown Quadrangle, Penna.; U.S. Geol. Survey Bull.840



CONOY CREEK AREA ENLARGED FROM MIDDLETOWN QUAD.

STOP 11. NAPPE STRUCTURES AND THE ANNVILLE QUARRY

Speaker: Carlyle Gray, Pennsylvania Geological Survey

Notes: Donald U. Wise, Franklin and Marshall College

I. Discovery of the Nappes.

A. Detailed stratigraphic and structural work on the limestones of the Greay Valley resulted in the discovery of major overturning and nappe structures by the members of the Pennsylvania Geological Survey.

B. These were described by Gray at the 1959 Geological Society of America Meetings:

> "Recent detailed studies in the Berks and Lebanon counties area of the Great Valley have indicated large-scale recumbent folds, or nappes, in the carbonate rocks. There are also indications of the presence of similar structures outside the area of detailed mapping. The area of recumbent folding has a strike length of at least 20 miles. The nappe is at least 4 miles wide and may be much wider, as the axis and root have not been definitely located. The structures are therefore on an Alpine scale.
>
> "The relation of the nappes to the crystalline basement is not yet completely clear. Where the nappes are best developed the basement is hidden by Triassic structures and deposits. At the east end of the area of detailed mapping, crystalline rocks are locally thrust over the younger carbonates. Here the basement apparently rises steeply on a series of moderate- to high-angle thrusts. It is also believed that a similar situation exists at South Mountain in Cumberland County, Pennsylvania."

C. The maps of the Lebanon and Richland Quadrangles by Gray, Geyer, McLaughlin, and Moseley (1958) are the basic data on which the interpretation was based.

1. A redrafted version of these maps is presented in figure 18.

2. THE ANNVILLE QUARRY IS JUST OFF THE WEST END OF THIS MAP.

II. The Annville Quarry.

A. There is no single stop at which the nappes can be seen readily.

1. We stop at the Annville Quarry to show some of the style of deformation and to provide a place to discuss the nappe problem.

B. Rock type is in the Ordovician Beekmantown group.

1. Axial planes of folds dip at moderate angles to the south.

C. Entire area from here south to the Triassic, 4 miles away, is overturned.

1. This location is right on line with the geologic section of figure 18 as redrafted from Gray, et al (1958).

III. Significant Features of the Nappes from Gray, Geyer, et al (1958) maps.

A. The area from here south to the Triassic is overturned.

1. Younger beds dip southward under older beds for a distance of four miles.

2. See profile in figure 18 from Gray's work. Annville quarry would be just off the left (north) end of this section.

B. Cleavage and axial planes of minor folds are nearly horizontal where mapped.

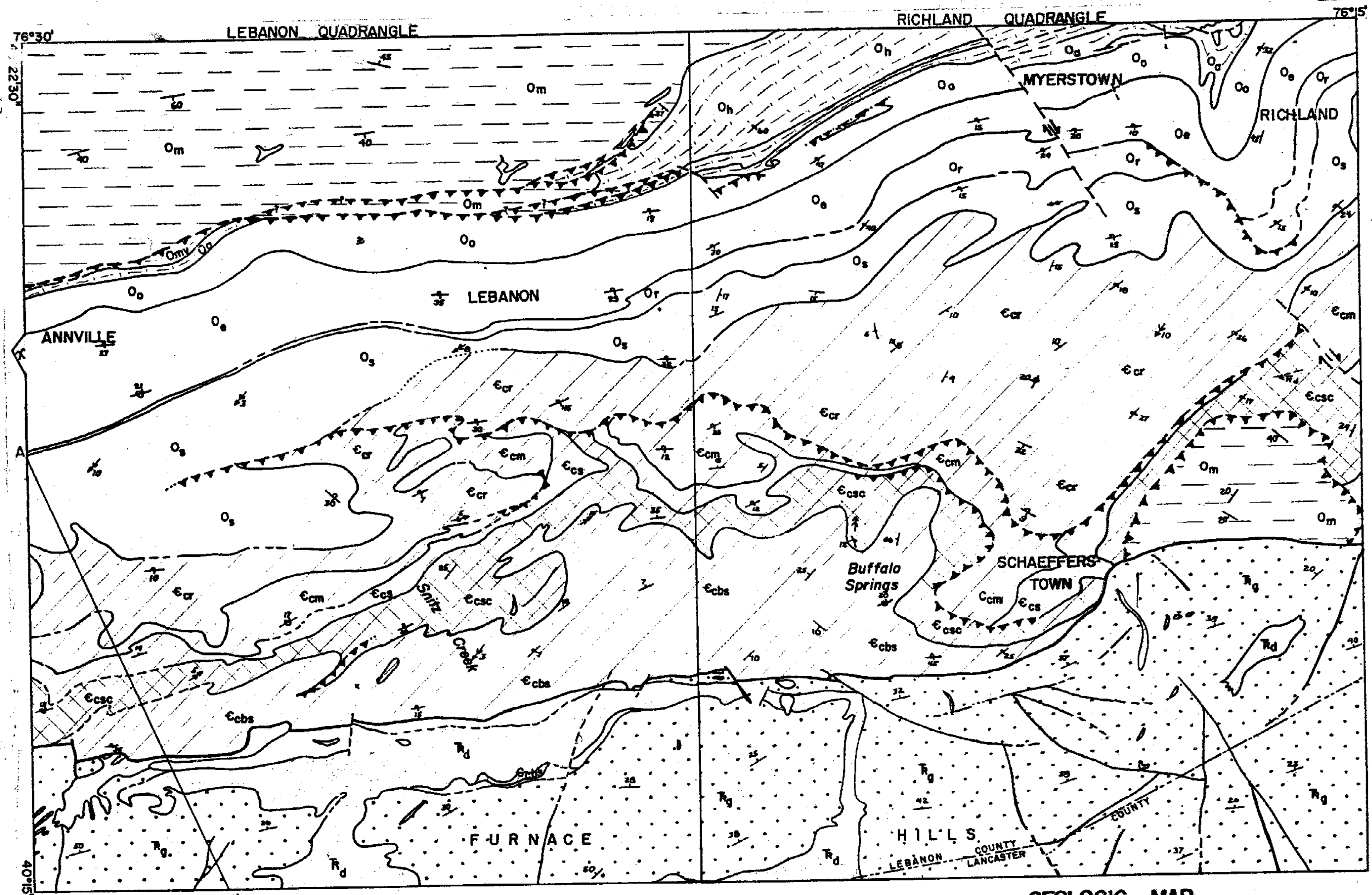
1. These recumbent axial planes are shown nicely on the sections by Gray.

2. The axial planes are gently warped in an open fold pattern, so that anticlines and synclines could be distinguished in the S_2 surfaces.

C. The faults are in general parallel to bedding.

1. Geologic sections are drawn to show considerable movement parallel to the overturned bedding surfaces.

D. In the southeastern part of the Richland Quadrangle is a klippe of Martinsburg shale 1x2 miles in length resting on the upside down units of the lower Conococheague.



EXPLANATION

TRIASSIC
- Ŧd — Diabase
- Ŧg — Gettysburg fm

ORDOVICIAN
- Om — Martinsburg fm
- Oh — Hershey ls
- Omy — Myerstown ls
- Oa — Annville ls

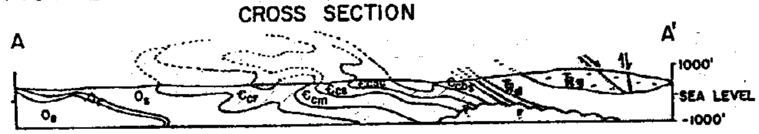
BEEKMANTOWN GP:
- Oo — Ontelaunee fm
- Oe — Epler fm
- Or — Rickenbach fm
- Os — Stonehenge fm

CAMBRIAN
CONOCOCHEAGUE FM:
- Ꞓcr — Richland mbr
- Ꞓcm — Millbach mbr
- Ꞓcs — Schaefferstown mbr
- Ꞓcsc — Snitz Creek mbr
- Ꞓcbs — Buffalo Springs mbr

SCALE
½ 0 1
miles

FIGURE 18

CROSS SECTION



GEOLOGIC MAP
OF THE
LEBANON & RICHLAND QUADRANGLES
(After Gray, Geyer, McLaughlin & Moseley, 1958)

Compiled by
M.E.Kauffman, 1960

Nappe Structures and the Annville Quarry
(Continued)

E. The Triassic border faults and Triassic sediments transect the nappe structures on the south and hide them from view.

IV. Nappe structure south of the Triassic cover.

A. The structure at Rheems Quarry is ample evidence that a similar environment existed for the deformation of the limestones south of the Triassic Belt.

B. In the Lancaster Quadrangle, Jonas and Stose (1930) showed overturned dip symbols in the limestones south of the Triassic cover but did nothing more with the problem.

C. Mapping by senior students at Franklin and Marshall College has shown that large protions of the Lititz and the Ephrata 7-1/2 minute quadrangles are overturned.

1. Many of Gray and Geyer's units have been recognized in the limestones.

2. The axial planes of the folds steepen sharply in dip in the area southeast of Lititz, suggesting some kind of a root zone in that general area.

3. On about fifty of the bedding surfaces in the area north and east of Lititz very consistently oriented lineations have been found which appear to be a kind of "smearing" or flow lineation. This consistent "flow" direction is N40W.

4. Much more work needs to be done on this southern extension of nappes, particularly in working out the more precise location and nature of their root zone.

D. On the basis of this preliminary work in the south, it appears that the zone of overturning and nappe development is approximately 16 miles wide across the strike from Gray's detailed work in the north to the zone in the south where the axial planes seem to steepen markedly in dip.

STOP 12
ORDOVICIAN VOLCANICS OF THE BUNKER HILLS, LEBANON COUNTY, PENNSYLVANIA

Owen Bricker
Harvard University
(Portion of Masters Work at Lehigh University)

The Jonestown volcanics which lie south of Jonestown, Pennsylvania, form a topographic high known locally as the Bunker Hills. The area was first brought to attention by S. G. Gordon (1927) who recognized the basaltic flows and intrusions of diorite in the Martinsburg formation. Stose and Jonas (1925) interpreted the Jonestown volcanics as a downfaulted block of the Triassic due to structural and lithologic similarities existing between these rocks and rocks of Triassic age occurring a few miles to the south. Two years later after a re-examination of the area, Stose and Jonas (1927) concluded that the volcanics were Ordovician in age, stratigraphically located near the base of the Martinsburg formation.

Except for a few unidentified micro-fossils found in one of the limestones, no fossils have been discovered in the sedimentary rocks associated with the volcanics. The lack of fossils in the surrounding sedimentary rocks makes it impossible to date the flows by paleontological means. Dating of the diorite and basalts by the Helium method was attempted by W. D. Urry (1936). The ages he obtained for the diorite were $375 \times 10^6 \pm 15$ and $355 \times 10^6 \pm 15$ while the ages he obtained for the basalts were 140×10^6 and 145×10^6 years. He noted that the dates obtained for the diorite were reliable while those obtained for the basalts were probably not reliable due to the weathered condition of the basalt samples.

The stratigraphic position of the Jonestown volcanics within the main belt of the Martinsburg formation leaves no doubt that the volcanics are Ordovician in age.

Lithology

The Jonestown volcanics are interbedded with a series of shales, sandstones and limestone. A complete stratigraphic section is difficult to obtain because of faulting and depositional irregularities. The following is believed by the writer to be reasonably accurate:

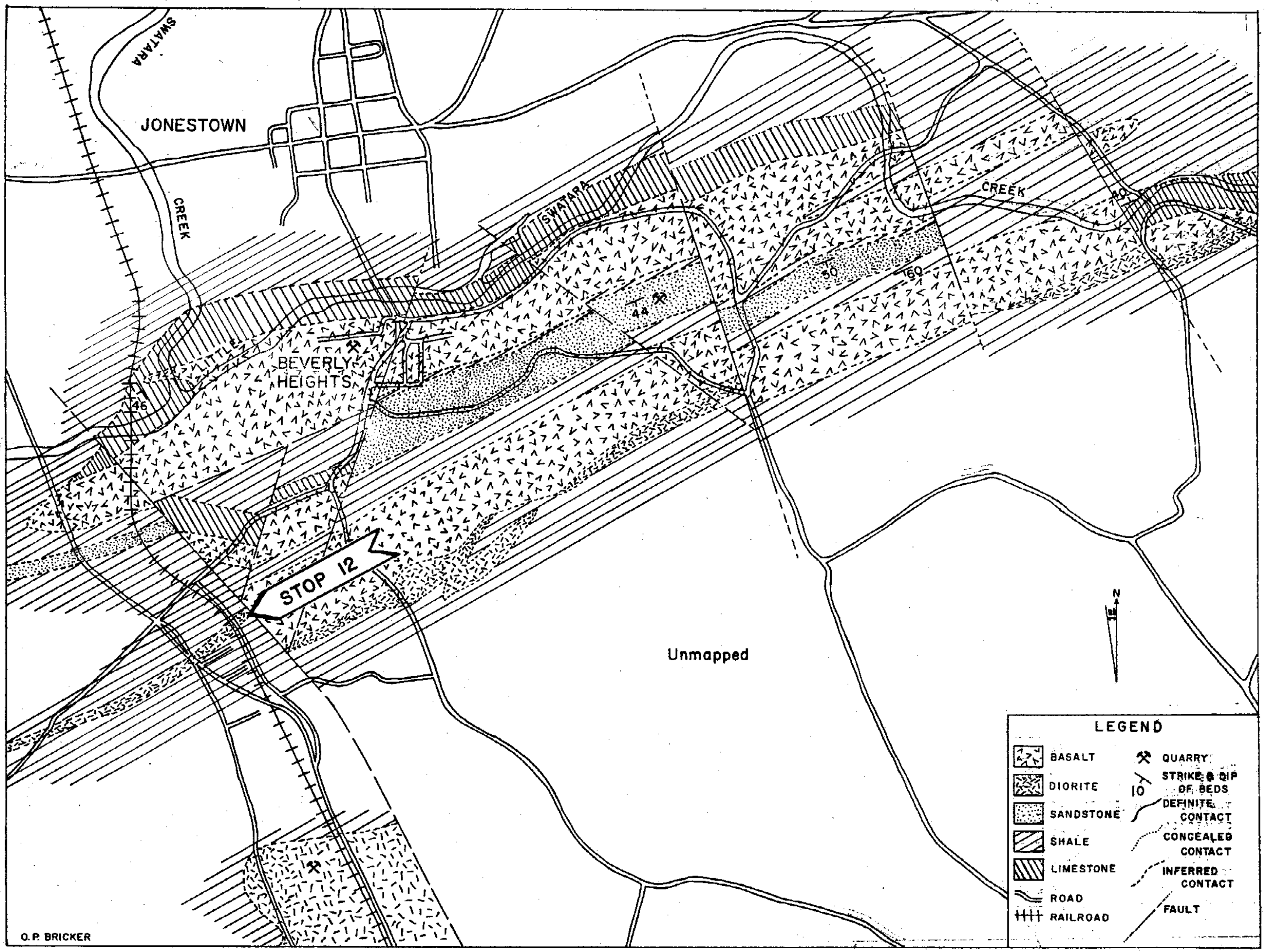
Stratigraphic Section From North To South Across The Bunker Hills

Description of Horizon	Estimated Thickness
Top	
Dark gray to black fissile shale	?
Fine to medium grained blue-gray limestone	150±
Dark greenish-gray basalt breccia, massive basalt and amygdaloidal basalt	500±
Dark gray shale containing thin beds of red, purple and green shale	50±
Hard white sandstone containing angular fragments of green clay	150±
Dark gray shale containing beds of red and purple shale, green arkosic sandstone and thin impure limestone	125±
Red basalt breccia, massive basalt and some porphyritic basalt	600±
Dark gray shale, green arkosic sandstone, thin beds of red shale	?
Base	

All of the diorite intrusions occur to the south of the southernmost flow. The thick limestone and hard white sandstone occur locally with the volcanics. The red and purple shales are more abundant within close proximity to the volcanics than elsewhere within the Martinsburg formation. It seems likely that the Jones-town area was an isolated or partially isolated unstable area in the basin of deposition where conditions changed rather rapidly producing the combination of rocks found there today.

The shales occurring to the north of the volcanics are dark gray to black fissile shales which weather to light brown. A series of thin greenish sandstones which weather to dark brown occur within these shales. The shales occurring to the south of the volcanics are similar in appearance but contain more beds of greenish sandstone as well as some thin beds of red shale. Within the volcanics the red shale is more prevalent and a purple shale occurs which has not been observed elsewhere in the vicinity. Thin beds of greenish sandstone and argillaceous limestone also occur in these shales.

The limestone associated with the volcanics is a thick bedded, fine to medium grained, blue-gray limestone, which at some places reaches a thickness of 150 feet. The limestone can be traced in many places by abandoned quarry pits along its strike. In several of these abandoned quarries the basalt-limestone contact is exposed showing the basalt lying directly upon the limestone. In a few places thin black shale not exceeding a thickness of several feet occurs between the basalt and the limestone.



JONESTOWN VOLCANICS

SCALE 0 — 1 MILE

FIGURE 19

The sandstone is a coarse-grained white arkosic sandstone containing angular fragments of light green clay roughly oriented along the bedding planes. The clay fragments might represent accumulations of volcanic dust. However, their origin remains a matter of speculation at the present time. In quarries the sandstone is soft and friable while along the ridges where it has been exposed to weathering, it is very hard and resistant.

Megascopically several differing basaltic rocks can be distinguished. The north ridge of the Bunker Hills is underlain by a highly altered dark greenish-gray basalt attaining a maximum thickness of about 500 feet. At the base it is strongly brecciated containing fragments of the underlying limestone but grades upward into more massive rock. Throughout the basalt, amygdules filled with calcite, epidote and some quartz can be found. In some horizons they are very abundant whereas in others they are not. This suggests that the north Bunker Hills might be a series of flows rather than one single flow with the profusely amygduloidal horizons representing the tops of the individual flows. Not enough outcrop exists to trace these horizons within the basalt. Structures resembling pillows can be observed at several localities.

Microscopic examination shows the basalt to be spilite consisting of laths of sodic feldspar with the interstitial spaces filled with chlorite minerals, calcite, and epidote. Large relict grains of pyroxene which have been completely altered to chlorite minerals and actinolite occur abundantly within the basalt.

The basalt underlying the south ridge of the Bunker Hills is reddish in color, contains phenocrysts of feldspar at places and is not amygduloidal. The base of this flow is highly brecciated and grades upward into a massive non-brecciated rock. The flow reaches a thickness of about 650 feet at its maximum. Abundant jasper and epidote are associated with this flow.

A detailed petrographic investigation has not yet been made on this rock but a cursory examination shows the chlorite minerals are less abundant whereas actinolite and the opaque minerals are more abundant than in the basalt of the north Bunker Hills.

The intrusions lying to the south of the volcanics consist of medium to coarse grained quartz diorite. These like the volcanics are highly altered. The feldspars have been saussuritized and the mafic minerals altered to serpentine minerals imparting the green color to the rocks.

The strike of most of these intrusions parallels the strike of the sediments but since no exposure indicating the dip has been observed, they may be either dikes or sills.

Structure

The structure in the Jonestown area seems to be controlled mainly by a series of faults criss-crossing the general northeast trend of the formations. These faults are prominent in the competent formation of the volcanics but die out quickly in the shales to the north and south. These cross faults are easily traced by the offsetting of competent beds. Their dips as observed from exposures in quarries range from 20^{o} to 80^{o}. One strike fault occurs near the western end of the volcanics causing a repetition of a part of the sequence.

All of the formations dip to the south with the exception of one exposure of limestone along the Swatara Creek. This limestone appears to dip to the north. However, bedding in this outcrop is obscure and the reading is questionable. The breccia at the base of the basalt flows indicates that the flows are not overturned. This conclusion is substantiated by the few crude crossbeds observed in the white sandstone. The basalt therefore must be older than the diorite and if Urry's age dates are correct, older than $350x10^{6}$ years.

This unusual sequence of shale, sandstone, limestone and basalt is a rare, if not unique, occurrence in the Appalachian Mountain chain and deserves more attention than it has previously received.

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Itinerary for a Short Side Trip in the Bunker Hills

Owen Bricker

Leave Lebanon on Route 72 and proceed north 4.9 miles. Road crosses Martinsburg formation. Many of the higher ridges are underlain by diorite intrusions.

0.0 STOP 1. BACHMANS QUARRY

Quarry in one of the larger diorite bodies. Jointing is well developed and slickensides are abundant. Note green appearance of diorite due to alteration.

Continue north on Route 72.

0.2 Bear right.

0.8 Outcrop along road.

STOP 2. LIMESTONE OUTCROP

Typical limestone associated with the Jonestown volcanics. The limestone at this locality occurs in a fault block which has been twisted in relation to the usual north-east trend of the formations. It is bounded on the north by a strike fault which causes a repetition of a part of the sequence. This is the only place where a repetition occurs.

Continue east on road.

1.0 Turn left.

1.4 Park on south side of bridge.

STOP 3. CREEK QUARRY

Typical basalt breccia of the north Bunker Hills. Amydgules filled with calcite, epidote and some quartz. Pillow structures have been reported from this locality. Look for fragments of limestone in the breccia.

Leave quarry on same road.

1.5 Turn east along the Swatara Creek.

2.3 Sandstone quarry. Note offset in sandstone ridge where it crosses road.

STOP 4. SANDSTONE QUARRY

White arkosic sandstone occurring with the volcanics. Bedding dips to the south at about 40°. Note the green clay fragments. In many places these fragments are roughly oriented in the plane of bedding. Outcrop of sandstone on the top of the ridges is hard and resistant as opposed to the soft friable nature of the sandstone in the quarry.

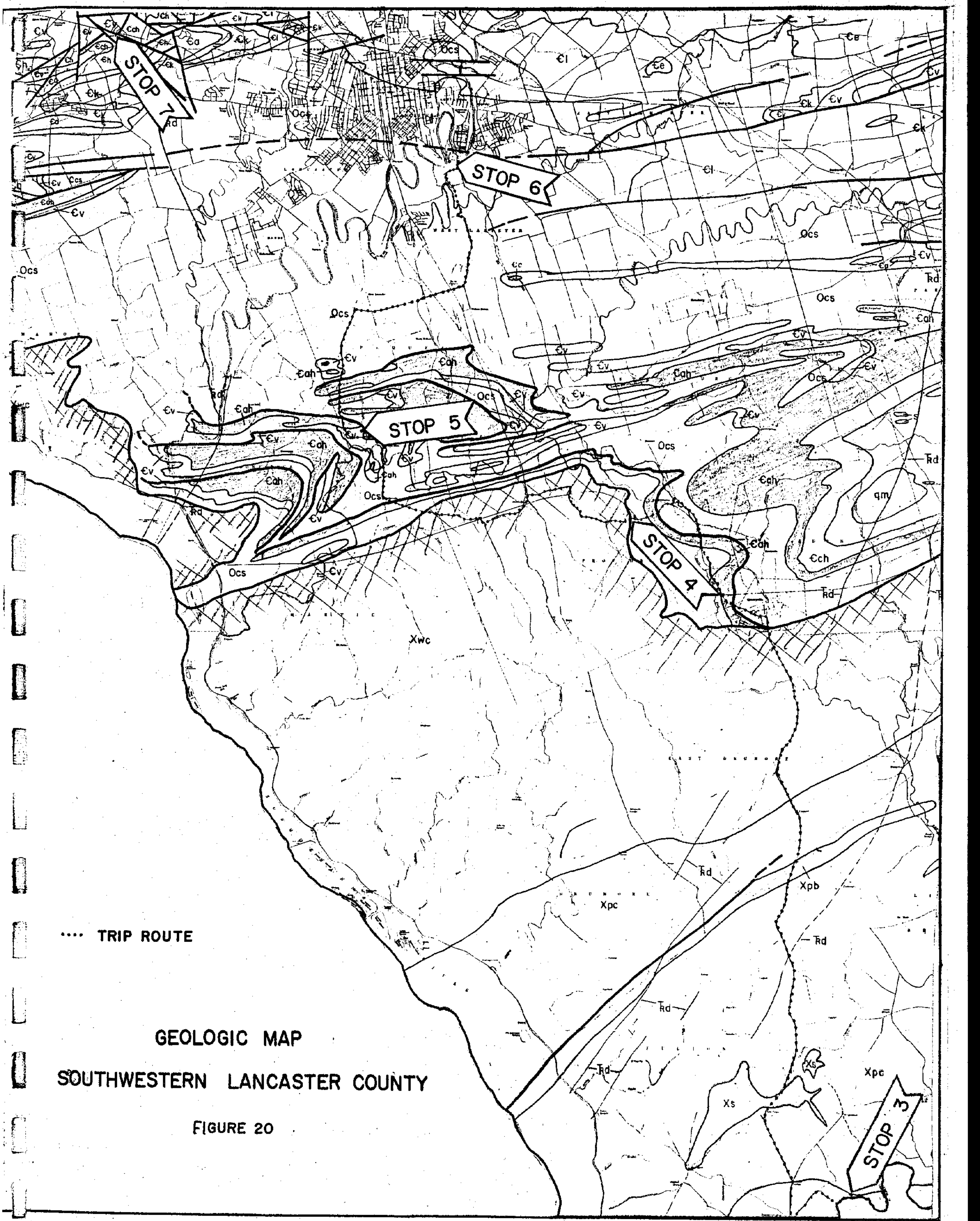
Turn around.

Retrace route back to Beverly Heights, turn left and proceed 0.6 mile.

STOP 6. BASALT BRECCIA

This is the typical red breccia of the south Bunker Hills. Abundant jasper and epidote are associated with the south flow.

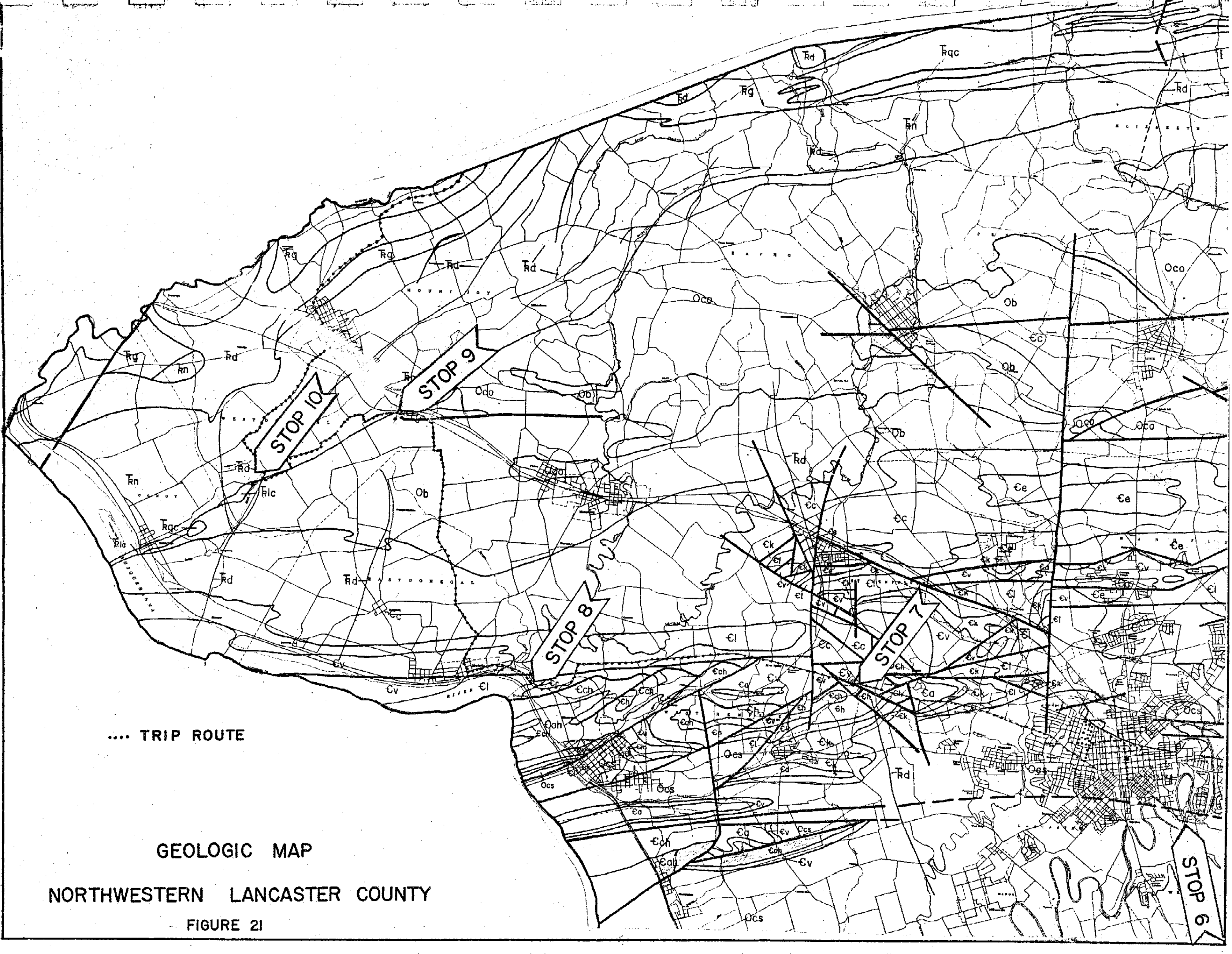
Turn around at top of hill and proceed north to first left turn. Bear left and return to Route 72.



GEOLOGIC MAP

SOUTHWESTERN LANCASTER COUNTY

FIGURE 20



GEOLOGIC MAP

NORTHWESTERN LANCASTER COUNTY

FIGURE 21

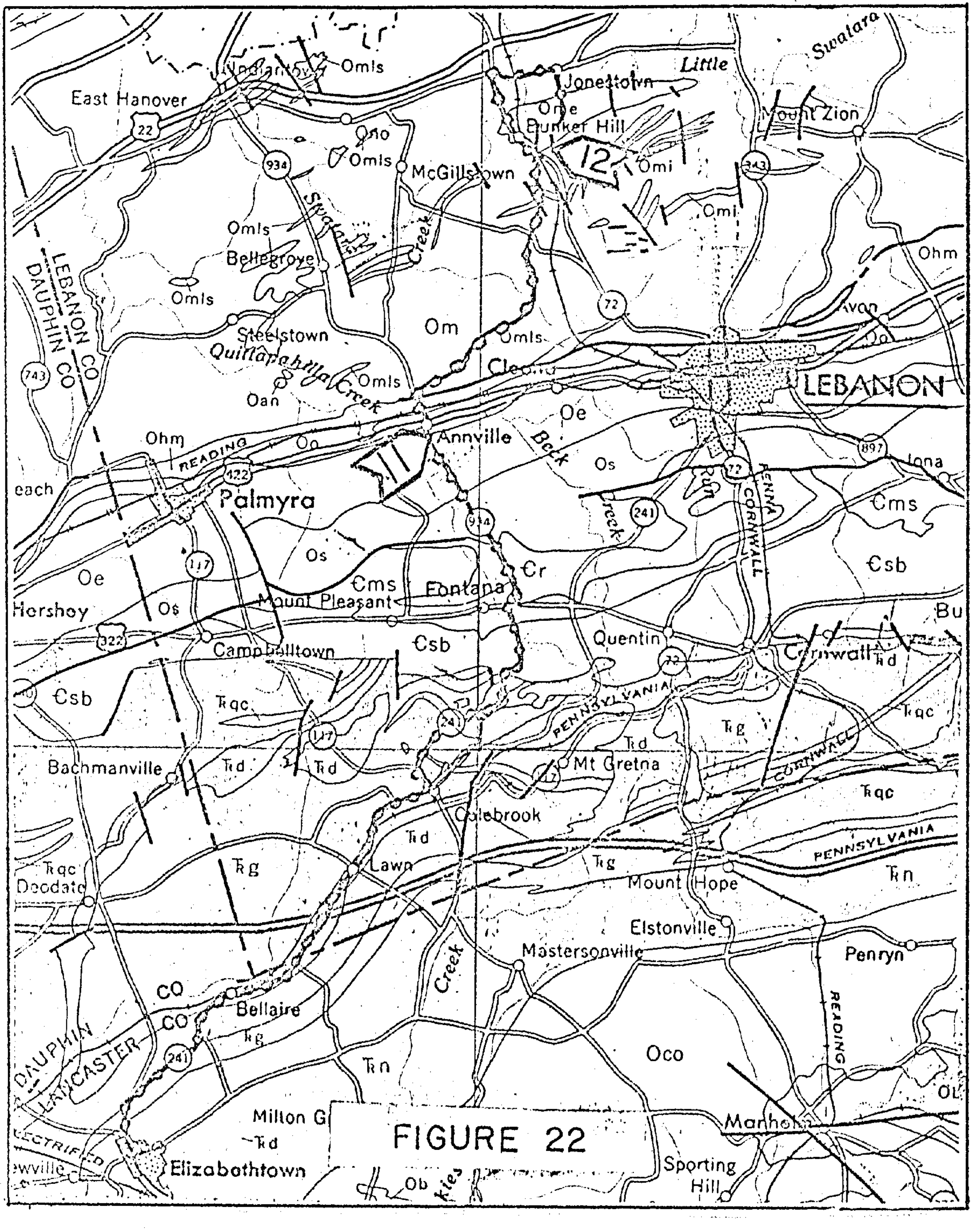

Swatara
Little
Jonestown
Mount Zion
East Hanover
Omls
Bunker Hill
Omi
McGillstown
Bellegrove
LEBANON CO
DAUPHIN CO
Om
Ohm
Avon
Steelstown
Quittapahilla Creek
Cleona
LEBANON
Oan
Oe
Annville
Ohm
READING
Palmyra
Os
Iona
Cms
Csb
Fontana
Mount Pleasant
Hershey
Quentin
Campbelltown
Cornwall
Bachmanville
Mt Gretna
Colebrook
Lawn
Mount Hope
Elstonville
Penryn
Mastersonville
Bellaire
DAUPHIN
LANCASTER
Oco
Milton G
Manheim
Elizabethtown
Sporting Hill

FIGURE 22