

# GUIDEBOOK

## TWENTY-FIRST ANNUAL FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

May 27, 28, 29, 1955

1855



1955

## CENTENNIAL YEAR

### THE PENNSYLVANIA STATE UNIVERSITY

UNIVERSITY PARK, PA.

Guidebook

TWENTY-FIRST ANNUAL FIELD CONFERENCE

OF PENNSYLVANIA GEOLOGISTS

Host

The Pennsylvania State University  
University Park, Pennsylvania

May 27, 28 and 29, 1955

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## Program

Friday, May 27

- 1:30-5:30 PM      Stratigraphy of Ordovician limestones and dolomites of  
Nittany Valley. F.M. Swartz, M. Roncs, A.C. Donaldson,  
J.P. Hea.
- 6:30 PM            Dinner, The Nittany Lion Inn. Address of Welcome by Dr.  
E.F. Osborn, Dean College of Mineral Industries.  
Discussions of Saturday and Sunday Programs.

Saturday, May 28

- 8 AM - 5:30 PM      Stratigraphy and Structure of Ridge and Valley area from  
University Park to Tyrone, Mt. Union, and Lewistown.  
F.M. Swartz, Petrology of Bald Eagle and Juniata  
formations. P.D. Krynine.
- 7:30 PM            Electron Microscopy of Clay. T.F. Bates.  
Uranium of the Colorado Plateau. J.C. Griffiths  
Auditorium, Mineral Sciences Building
- 8:30 PM            Visits to Geology, Coal Petrography, Mineralogy and  
Mineral Constitution Laboratories.

Sunday, May 29

- 8 AM - 2 PM        Structure and Stratigraphy of Pennsylvanian sediments of  
the Plateau Area near Philipsburg and Clearfield.  
R.P. Nickelsen and E.G. Williams.

### General Plan of Field Trip

The Twenty-First Field Conference will provide a general review of the geology of central Pennsylvania. Three trips have been arranged for this purpose. On Friday, May 27, Early and Middle Ordovician sediments will be examined in Nittany Valley. The second trip, on Saturday, will make a wider traverse of the Ridge and Valley area during which attention will be devoted chiefly to Late Ordovician, Silurian and Devonian rocks and to the structural features of the region. The conference will conclude on Sunday with an examination of Pennsylvanian sediments well exposed in strip mines of the Allegheny Plateau area.

Twenty-First Annual Field Conference of  
Pennsylvania Geologists

Friday Afternoon Trip  
1:30 to 5:30 PM, May 27, 1955

Stratigraphy of Ordovician limestones and  
dolomites of Nittany Valley in area from Bellefonte  
to Pleasant Gap, Pennsylvania

F.M. Swartz, M. Roncs, A.C. Donaldson,  
J.P. Hea

The localities that will be visited in the area from Bellefonte to Pleasant Gap expose a large part of the 5000 feet of Middle and Lower Ordovician limestones and dolomites of the region, in areas where important stratigraphic contributions have been made by Collie, Ulrich, Butts, Field and Kay. The sections occur across the crest and in neighboring parts of the flanks of the Nittany Valley arch, which is the largest and most highly elevated as well as the most northwesterly of the anticlinoria that bring Cambro-Ordovician sediments to ground surface in Pennsylvania northwest of the Great Valley. The trip will also provide an introduction to the general geology, geomorphology and structure of the region, providing background for the trips of the following days.

In the report on Centre County by D'Invilliers published by the Pennsylvania Second Geological Survey in 1884, all of the limestones and dolomites of Nittany Valley were included in formation No. II, termed the Trenton, Chazy and Calciferous. An important forward step, initiating the subdivision of these strata and presenting extensive information about fossils useful for correlation, was accomplished by Collie in 1903 when he distinguished the following lithologic and faunal sequence near Bellefonte.

Lorraine state, 350 feet: gray and brown shales, some thin beds of sandstone and ferruginous limestone in upper part.  
Cyrtolites ornatus, Byssonichia cincinnatiensis fauna.

Utica stage, 650 feet: dark fissile shales, alternating with brownish shales in upper part and containing some thin beds of sandstone near middle. Triarthrus becki fauna in lower half.

Trenton stage, 603 feet: black limestone, with interbeds of dark shale and containing layers of gray crystalline limestone in middle and upper part. Trinucleus concentricus, Ceraurus pleurexanthemus, Isotelus platycephalus, Plectambonites sericea fauna, with Brongniartia trentonensis in lower part.

Black River stage, 93 feet: black shaly limestone alternating with thick beds of gray limestone. Maclurea bigsbyi, Strophomena filitexta fauna.

Stones River stage, 253 feet: crystalline black limestone alternating with light gray limestone: Leperditia fabulites, Protorhyncha ridleyana fauna.

Beekmantown stage, 4803 feet: including at top 2335 feet of compact yellowish gray and drab dolomitic limestone, underlain by 2468 feet of limestones and dolomitic limestones subdivided into 13 lithologic units, containing Bathyrurus amplimarginatus, and Maclurea affinis in uppermost 157 feet, Asaphus marginalis fauna in beds 1424 to 1746 feet below top, Ophileta complanata in beds 2068 to 2283 feet below top.

Collie reported that he was aided with faunal determinations by Ulrich and others. In 1910 Ulrich published a further account of the Bellefonte section and its faunas, in which he divided the Beekmantown beds into four formations, namely the Bellefonte dolomite, Axemann limestone, Nittany dolomite and a lowest limestone which he identified with the Stonehenge limestone of the Chambersburg region.

Following the early studies of Collie and Ulrich, the Ordovician and Upper Cambrian sequences of Nittany Valley have received further investigation by Butts, Field and Kay, so that the following stratigraphic succession, given in descending order, can now be recognized in the Bellefonte-Pleasant Gap area below the Oswego or Bald Eagle sandstone that forms the nearest parts of the adjoining mountain ridges.

#### Ordovician System

#### Cincinnatian series

#### Maysvillian stage

Oswego sandstone (Emmons, 1846), 350 to 650 feet: also known as Bald Eagle sandstone (Grabau, 1909) from exposures near Tyrone.

#### Maysvillian and Edenian stages

Reedsville shale (Ulrich, 1911), 600 feet: dark gray finely micaceous shale, weathering yellowish brown, with subordinate, thin interlayers of

micaceous siltstone, and some thin interlayers of fossiliferous limestone. Resserella multisecta, Zygospira modesta var., Flexicalymene meeki fauna.

#### Edenian or Trentonian stage

Antes shale (Kay, 1944) 300 feet; dark gray to black, subfissile shale, weathering brownish gray. Triarthrus eatoni, Dicranocraptus nicholsoni fauna.

#### Champlainian series

##### Trentonian stage

Coburn limestone (Field, 1919) 400 feet; dark gray to grayish black aphanitic limestone with interbeds of medium gray coarsely crystalline coquinite; interbeds of shale increase in upper part so that formation intergrades with Antes shale. Cryptolithus tessellatus fauna, the numerous species also including Sowerbyella sericeus, Rafinesquina cf. alternata, R. deltoidea, Resserella rogata, Ceraurus pleurexanthemus, Isotelus spp., Calymene senaria. At base is zone of Parastrophia hemiplicata.

Salona limestone (Field, 1919) 200 feet; grayish black aphanitic limestone. Cryptolithus tessellatus, Brongniartella trentonensis fauna. Whitcomb, Rosencranz and Kay have discussed widespread occurrences of the yellowish-weathering bentonitic layers that are representative of falls of volcanic ash and that occur at Bellefonte as follows: No. 0, 1 foot above base of Salona, followed by No. 1 at 15½ feet, No. 2 at 18 feet, No. 3 at 37½ feet, No. 4 at 68 feet, and No. 5 at 104 feet.

Tusseyville limestone (Rones, ms.) 65 feet; includes Rodman limestone (Butts, 1918) 25 feet, underlain by Centre Hall limestone (Field, 1919) 40 feet; these are medium gray to medium dark gray limestones, that differ markedly from the grayish black aphanites of the overlying Salona and the medium gray to light medium gray calcite-specked calcilutites of the underlying Valentine limestone. The upper, Rodman limestone is much more crinoidal than the Centre Hall; as here interpreted the thin-layered argillaceous beds at the middle of the Tusseyville at Bellefonte are included in the upper Centre Hall, as was done by Kay at Tusseyville. Maclurites logani fauna. Tusseyville limestone is part of the Nealmont limestone of Kay, limited by removal of Oak Hall limestone.

Curtin limestone (Kay, 1943) 120 feet; includes Valentine limestone (Field, 1919) 80 feet, above, and Valley View limestone (Kay, 1943) 40 feet, below. The Valentine limestone is the important chemical limestone of the region, and, through much of its thickness, is formed of

beds having less than one per cent of silica, and low values of  $R_2O_3$  and magnesia. It is mined in the deep mines of the National Gypsum Company and Warner Company near Bellefonte, and at the deep mine of the Standard Lime and Cement Company and open cut quarries of the Whiterock Company near Pleasant Gap. The Valentine limestone consists predominantly of light medium gray to medium gray, conchoidally breaking calcilutite containing numerous specks of sparry carbonate that dominantly are fillings of small cavities formed in the lime mud early in its history of sedimentation and compaction. The No. A bentonite of Rosen-  
 cranz (1934) marks the base of the Valentine limestone as defined by Kay, and there are some thin bentonitic partings at higher levels. Several darker-splotched zones that retain high purity appear in the Valentine northeast of Bellefonte, and thicken gradually northeastward; they are thought to be tongues from the medium dark gray Oak Hall limestone. Fossils generally are few in the Valentine limestone, but there are some occurrences of Tetradium cellulorum, especially in the lower beds; there are also some rare valves of Eoleperditia cf. fabulites, and some conodonts have been observed in insoluble residues. The Valley View limestone below the Valentine contains layers B, C and D of Rosen-  
 cranz; its base was drawn by Kay in the type area at Bellefonte at the base of bentonite E; however, work by Roncs has shown that bentonite E at this locality corresponds to bentonite F as known 20 feet below the top of the type Stover limestone at Union Furnace 30 miles southwest of Belle-  
 fonte, and that Stover type lithology occurs widely above bentonite bed E - F in the general Bellefonte - Pleasant Gap area. In consequence, it has proven desirable to revise the base of the Valley View so that it is not lower than bentonite bed D. As a whole, the Valley View beds are medium gray to medium dark gray in color and are impure, containing several per cent of silica. Tetradium cellulorum is profuse in some beds of the Valley View limestone, especially in the higher parts. The dis-  
 sertation work of Roncs indicates that the Valley View like the Valentine grades laterally into the medium dark gray limestones of the Oak Hall limestone of Kay, which was included by Kay in the Nealmont limestone on the supposition that the Oak Hall is younger than the Valentine and Valley View, and rests on the disconformity which as Kay discovered progressively truncates older beds toward the southeast. In Kay's opinion, the fauna of the Oak Hall limestone warrants inclusion of the Oak Hall in the basal portion of the Trentonian stage, and if this view is supported by further faunal studies the interfingering Valentine and Valley View limestones with their more limited known faunas will likewise need to be classed as Trentonian. Interesting ostracodes that are now being discovered in Oak Hall and Centre Hall beds may aid future corre-  
 lations of these strata.

### Black River stage

Benner limestone (Kay, 1941) 155 feet, including Stover limestone (Kay, 1941) 80 feet, underlain by Snyder limestone (Kay, 1941) 75 feet. The Stover limestone is characterized by the presence of argillaceous-dolomitic streaks and mottlings which under certain conditions of weathering take on a "golden-weathering" appearance, and with further attack impart to weathered surfaces a complexly pitted, "worm-eaten" character. Bedding surfaces of the Stover are in many instances deeply furrowed, apparently by these same structures, giving them a striking "fucoidal" appearance. Seen in its weathered aspects, the Stover is one of the well defined formations of the Bellefonte area, although comparable surface pitting is also developed in the weathering of the Grazier limestone. The Stover beds are sparingly fossiliferous, but Kay states that Cryptophragmus antiquatus and Distactospongia can be observed on weathered surfaces. The Snyder limestone beneath the Stover lacks the streaks and mottlings of Stover type, and contains conglomeratic inter-layers characterized by white-weathering limestone pebbles; there are beds of oolites and calcarenites. Some of the upper layers are thin bedded and more impure, and have ripple marked bedding surfaces. At Union Furnace and Blairfour parts of the Snyder have been extensively quarried for blast-furnace stone, road-metal and balast. Tetradium cellulsum and T. fibratum are abundant in some beds, and the Snyder may be considered one of the several important Middle Ordovician horizons of the Tetradium corals.

Hatter limestone (Kay, 1941) 75 feet, including Hostler limestone (Kay, 1943) 50 feet, underlain by Grazier limestone (Kay, 1943) 25 feet. The Hostler limestone is impure, its beds containing 10 to 25 per cent of silica as reported by Kay for the section at Union Furnace. In the middle, more argillaceous and silty portion at Union Furnace, there are abundant specimens of Opikina and of other brachiopods and of bryozoa. Fossils generally are less numerous northwards toward Bellefonte. Upper beds of the Hostler are less impure, but have been differentiated from the basal beds of the Snyder by lack of the conglomerates with white-weathering limestone pebbles. Below the Hostler, the Grazier limestone consists of medium dark gray, aphanitic limestone, with argillaceous-dolomitic patches as well as orange-stained sparry carbonate. The rock weathers with "worm-eaten" surfaces somewhat suggestive of those of the Stover limestone. Fossils include Tetradium syringoporoides and Gonioceras sp.

### Chazy stage

Loysburg limestone (Field, 1919) 340 feet. Includes at top the Clover limestone (Kay, 1941) 40 feet, underlain by Milroy limestone (Rones, ms.) 300 feet. The Clover limestone includes medium gray, more or less calcilutitic, in part laminated limestones; exposed beds at the Bellefonte section are comparatively impure and weather with yellowish

gray, earthy surfaces. The name Milroy is proposed by Roncs for the "tiger-striped" beds of Kay's reports, in which the dolomitic bands of irregular, 1-inch to 2-inch interlayers of dolomitic limestone and purer limestone weather with distinct relief on many of the exposed surfaces that transect the bedding of the rock. Fossils are rare in the Loysburg limestone, and correlation is based on stratigraphic position below beds of the Black River stage as now understood, and above the Bellefonte group which has been referred to the Canadian series since the days of Collie and Ulrich.

#### Canadian series

Bellefonte group (Ulrich, 1910) 1200-1400 feet. Includes at top Tea Creek dolomite (Swartz, Roncs, Macaulay, ms.) 200 feet, underlain by Coffee Run dolomite (Swartz, Roncs, Macaulay, ms.) 1000 to 1200 feet. The Tea Creek dolomite consists almost wholly of medium gray, in part red-flecked dololutite that weathers light, more or less yellowish gray, the weathered surface tending to be deeply gashed by incisions leached along fractures that transect this type of rock. The Tea Creek dolomite is one of the most distinctive and readily mapped rocks of the limestone valleys of central Pennsylvania, and tends to be associated with low ridges that contribute a subdued lineation to the surface of the valley floors. At or close to its base is the Dale Summit sandstone member (Swartz, Roncs, Macaulay, ms.), 0 to 20 feet, that was recognized and extensively mapped by Butts. Butts cited the exposures of the sandstone at Dale Summit, and commented upon the perfectly rounded, white sand grains, the locally conglomeratic character with pebbles of limestone and less commonly of chert and quartz, and occurrence of small unidentifiable fragments of trilobites and gastropods. Interesting petrographic features of the sandstone have been described by Krynine. The Coffee Run dolomite member contains layers of dololutite that approach the dololutite of the Tea Creek in character, but these tend to be overshadowed by interbeds of finely crystalline to medium crystalline dolomite that weather medium to medium dark somewhat brownish gray in color. The differences between the Tea Creek and Coffee Run dolomites are well exhibited in the type sections along the streams in Kishacoquillas Valley from which the names are derived, where studies were undertaken preparatory to mapping in the Valley by Roncs and Macaulay in 1951. Cyclic occurrences of dolomites of differing texture, fabric and color occur in parts of the Coffee Run. Fossils are rare in both the Tea Creek and Coffee Run dolomites. In addition to the unidentifiable fragments of trilobites and gastropods in the Dale Summit sandstone member, some specimens of Hormotoma suggestive of H. artemesia have been reported in Coffee Run horizons. These occurrences seem inadequate for satisfactory correlation; Kay has suggested that more attention might be given the possibility that the Dale Summit sandstone represents the inauguration of Chazy sedimentation.

Axemmann limestone (Ulrich, 1910) 375 feet; medium gray to medium dark gray aphanitic limestone, with rarer beds of finely to coarsely crystalline, in part calcarenitic and oolitic limestones, and with interlayers of finely crystalline to medium crystalline dolomite, the whole forming a limestone sequence that contrasts with and provides the basis for separation of the overlying Bellefonte dolomite and underlying Nittany dolomite, in which the grays of the weathered surfaces have somewhat yellowish to brownish tones. Fossils are numerous at some horizons, especially in the oolitic layers, and include the species Maclurites ("Maclurea") affinis and Jeffersonia ("Bathyrurus") amplimarginata that were reported by Collie as well as Hormotoma artemesia and other species first recognized by Ulrich. These three species especially give evidence for correlation with the upper middle to upper part of the Beekmantown group of the Champlain Valley and adjacent areas of Canada. Additional fossils having marked Beekmantownian affinities include species of Isoteloides and of Bathyrella near B. caudatus found by G.R. Macaulay in thesis work on the faunas of the Axemann in Kishacoquillas Valley and at Axemann; the peculiar character of the pygidial segmentation of the species of Bathyrella should make them especially valuable for future zonal work. Although correlation with the Beekmantown of other regions is fairly well established, the disappearance of the Axemann southwestward in parts of the Tyrone and Hollidaysburg quadrangles raises questions concerning the role of changes in facies versus non-deposition or erosion, and thus concerning the paleogeography and tectonics that governed sedimentation. To attack this problem, J.P. Hea has undertaken a dissertation in which he will use detailed studies of sections and of recognizable lithobodies and faunal horizons, to try to establish the nature of progressive changes in relations of the limestone and the enclosing dolomites.

Nittany dolomite (Ulrich, 1910) 1200 feet; medium gray, finely crystalline to coarsely crystalline, in part vugular dolomite, weathering medium to medium dark somewhat brownish gray, generally is dominant, the surfaces pock marked by pits that measure 1 to 2 inches in diameter. In parts of the formation the medium to coarsely crystalline dolomites alternate more or less rhythmically with finer textured and aphanitic dolomites, each type weathering with a different color. Fossils are rare, but include species of the middle Canadian genus Lecanospira, whose representatives are found in Missouri, in the Appalachians from Alabama into northeastern New York and Canada, in Newfoundland and in northern Scotland.

Stonehenge limestone (Stose, 1908) 500 feet; aphanitic to finely crystalline, medium dark gray limestone with irregular dolomitic streaks and bands; there are interlayers of calcarenites and oolites, numerous beds of flat-pebble limestone conglomerate, and some beds of finely crystalline dolomite, the formation as a whole contrasting with the overlying and underlying dolomites. At top is the Bellefontia collieana fauna, with species of Hystericurus close to the widespread H. conicus;

Ophileta complanata and Finkelburgia cf. F. wempli occur at lower levels. As in the case of the Axemann limestone, mapping by Butts shows disappearance of the Stonehenge toward the southwest at many localities. In his dissertation work, A.C. Donaldson has found it possible to subdivide lithologies and faunas, and by tracing these members through carefully studied sections is attempting to work out the relations of the Stonehenge to the enclosing dolomites. The Larke dolomite near Williamsburg may be partly of Stonehenge age.

## Cambrian System

### Upper Cambrian series

#### Trempealeauian and Franconian stages

Mines dolomite (Butts, 1918) 250 feet; finely crystalline to medium crystalline dolomite, weathering light to dark somewhat brownish gray; there are interlayers and nodular zones of chert that is in considerable part oolitic, and in part contains silicified Cryptozoa spp. suggestive of C. proliferum and C. undulatum. Other fossils are rare; gastropods of the genus Sinuopea found near Williamsburg have been identified with species of the Van Buren formation of Missouri.

Gatesburg dolomite (Butts, 1918) 1500 feet. Aphanitic to medium crystalline dolomite, differing types weathering light to dark, somewhat brownish gray, in part arenaceous and containing subordinate interbeds of arenaceous dolomite and of dolomitic quartzite, so that surface becomes covered with a thick, acidic and rapidly drying soil so that Gatesburg areas form Barrens with few areas of cultivation. Cyclic sedimentation has been recognized in the Gatesburg southwest of Tyrone by Pelt (1942). In the Hollidaysburg quadrangle, the Ore Hill limestone member (Butts, 1918), 50 to 100 feet thick and about 500 to 600 feet below the top of the Gatesburg, contains a large suite of trilobites, including Elvinia roemeri of the Theresa of New York; Plethopeltis, Saratogia and Pelagiella of the Hoyt limestone of New York; Conaspis, Elvinia, Burnetia, Irvingella and Housia of the Franconia of Wisconsin.

#### Dresbachian stage

Warrior limestone (Butts, 1918) 1000 feet; medium to dark medium gray, aphanitic to finely crystalline limestone, weathering light medium gray; in part thinner bedded, argillaceous and micaceous. There are coarser grained, oolitic interbeds. Trilobites are common in some of the oolites, rarer in other beds; they include species of the Crepicephalus and Cedaria faunas. Cryptozoa cf. C. undulatum is common at some horizons, and forms some small bioherms thickening from zero to as much as 4 or 5 feet in distances of 10 to 20 feet.

## Middle and Lower Cambrian

The Warrior limestone is stratigraphically the lowest formation exposed in the Bellefonte quadrangle. Farther southwest in the Hollidaysburg quadrangle it is underlain by Pleasant Hill limestone (Butts, 1918) 600 feet, containing trilobites of the Middle Cambrian Alokistocare, Olenoides fauna; beneath this in turn there are small exposures of greensih to dark gray, in part purplish shales that contain fragments of Olenellus and Bommia and that have been referred to the Lower Cambrian Waynesboro formation.

Trip #1

Friday afternoon, May 27, 1955  
1:30 to 5:30 PM

Ordovician limestones and dolomites of Nittany Valley  
from Bellefonte to Pleasant Gap

Departure: At 1:30 PM; assemble on Park Avenue, State College,  
back of Nittany Lion Inn; use busses to avoid  
back-tracking to autos at the stops.

Topographic maps: Bellefonte, Centre Hall

ItineraryMiles

- 0.0 Northeast on Park Avenue, turning right and following macadam road at 0.7 miles. From 0.5 to 1.0 miles there are fine views of Nittany Valley and the surrounding mountain ridges, seen from the level of the Harrisburg peneplain. For routes of this and other trips, refer to multilithed, reduced scale, assembled topographic map sheet at back part of Guidebook.
- 1.0-1.7 Cross stop-sign intersections at 1.0 and 1.2 miles, and turn left on highway No. 545 at 1.7 miles. Nittany dolomite in left bank of road at 1.6 to 1.7 miles.
- 1.8-2.1 Axemann limestone dipping 20° SE is exposed in left bank of road.
- 2.2 On right: restored Centre Furnace, a relic of the pre-Lake Superior iron industry of central Pennsylvania.
- 2.5 Coffee Run (Bellefonte) dolomite in left bank of road.
- 3.2-3.3 Coffee Run dolomites on both sides of road; the dololutitic beds show characteristic multiple jointing.
- 3.5-3.6 Darker weathering, pock marked medium crystalline interbeds of the Coffee Run dolomite.
- 3.7 Small bridge over Spring Creek, at bottom of grade.
- 3.8-4.3 Tea Creek, upper Bellefonte dololutites, weathering light yellowish gray to grayish yellow, with gashed surfaces.
- 4.7 Bear left on Route 545 at fork in highway.

5.2-5.3 Coffee Run dolomite in road cuts.

5.3-7 Fine views of Nittany Valley and surrounding mountain ridges, seen from general level of Harrisburg peneplain. Shiloh Church on left and cemetery on right at 5.4 miles. Rockview Branch of State Penitentiary across fields on right at 6.3 miles.

7.1 Axemann limestone in road cuts.

7.4 Nittany dolomite in road cuts.

7.8 Penitentiary warden's residence on left.

8.3 Turn right on road to Axemann, just north of entrance on left to Station of The Pennsylvania State Police.

8.6 STOP 1: at intersection beside power line station. 20 minutes.

The stop affords a view toward the northeastern end of Nittany Valley, from a hilltop at an altitude of 1080 feet, a little below the common 1100 to 1200 feet of most of the flattened lands that represent the Valley Floor or Harrisburg peneplain. Bottoms of the valleys of the present stage of dissection are cut several hundred feet lower, reaching an altitude of little more than 700 feet at Milesburg Gap northwest of Bellefonte.

Bald Eagle Mountain, which bounds Nittany Valley along its north-westerly margin, has extensive summit areas at altitudes of 1600 to 1800 feet that have been attributed to the Schooley peneplain; where transected by Milesburg Gap it permits a view of Pocono sandstone-crested, 2200-foot summits of the Allegheny Front, that may represent the Kittatinny peneplain. Nittany Mountain, along the southeasterly margin of Nittany Valley, is synclinal as contrasted to monoclinical Bald Eagle Mountain; the nearer crests are made by Oswego or Bald Eagle sandstone, and have altitudes of 1900 to 2000 feet; the backbone of Tuscarora sandstone protected along the synclinal axis rises locally to more than 2200 feet.

Within Nittany Valley, northeast of Bellefonte, summits of Sand Ridge rise to altitudes of more than 1400 feet where moderately resistant Gatesburg dolomite and sandstone is uplifted along an updomed portion of the axis of the Nittany Valley anticline; the geographic offsetting of the ridge from the mid-line of the Valley gives evidence of the asymmetry of the anticlinal structure. Due to a saddle along the anticlinal axis, Gatesburg beds remain below ground level in the area immediately between Bellefonte and Pleasant Gap; though to the southwest, west of State College, they rise again to form Gatesburg Ridge and the Barrens. To the northeast, beyond Sand Ridge, the plunge of the anticline eventually merges the continuations of Bald Eagle and Nittany Mountains.

The anticline into which Nittany Valley has been eroded in the Bellefonte area, is part of the much larger Nittany Arch or anticlinorium, which continues to the northeast beyond Sunbury and Muncy until it merges with the folds of the Anthracite Basins, whereas toward the southwest it extends across Maryland and into West Virginia before losing its identity. The anticlinorium is a major structural feature of the region, and lies between the Broad Top synclinorium of comparable dimensions and the more extensive Allegheny Basin west of the Allegheny Front. It is the largest, most highly elevated and most northwesterly of the anticlinoria that bring Silurian and Cambro-Ordovician strata to levels of exposure northwest of the Great Valley.

The rocks of the floor of Nittany Valley are principally carbonates, or carbonites if this term is to receive usage. A basic framework results in part from successive alternations of bodies of dolomite and limestone, as well as from several striking changes within the limestones themselves. Ledges of one of the important dolomite formations, the Nittany dolomite, are exposed at Stop 1. The beds are evenly and rather finely crystalline, and weather with grayish brown surfaces marked by coarse pocks that in part seem to represent enlarged vugs, in part the solution of readily weathered pockets. Loose slabs that weather a darker gray and are in part somewhat coarser in texture, present on the whole a more characteristic aspect for the formation, although the Nittany dolomite like the other carbonate formations is complex and includes beds of divergent lithologies.

The Nittany dolomite is defined and separated from other thick dolomite bodies by the Stonehenge limestone beneath it, and the Axemann limestone above it. The weathered surfaces of the limestones tend to be light medium neutral, so-called "bluish" grays as compared to the somewhat brownish to yellowish grays of the dolomites. Beneath the Stonehenge are Mines dolomite with much oolitic chert, and Gatesburg dolomite with sandy layers. Above the Axemann is the Bellefonte dolomite group, characterized at its top by dololutites that tend to weather light yellowish gray to grayish yellow and to develop deep gashes by weathering along transecting joints. It is proving desirable to distinguish the Tea Creek or uppermost Bellefonte which is composed almost exclusively of this type of rock, from underlying Coffee Run dolomite, in parts of which there is predominance of more coarsely crystalline, pock marked layers resembling beds of the Nittany formation. Petrographic features in beds of the Bellefonte and Nittany dolomite, and Axemann and Stonehenge limestone have been described in an unpublished dissertation by R.L. Folk.

Above the Bellefonte dolomites, there was early recognition of upper black limestones containing the Cryptolithus tessellatus faunas of the typical Trenton, under which are gray limestones in which there was discovered a body of light-weathering, calcite-specked limestone of high purity that is extensively worked today in deep mines near Bellefonte and in a deep mine and extensive open cut quarries near Pleasant Gap.

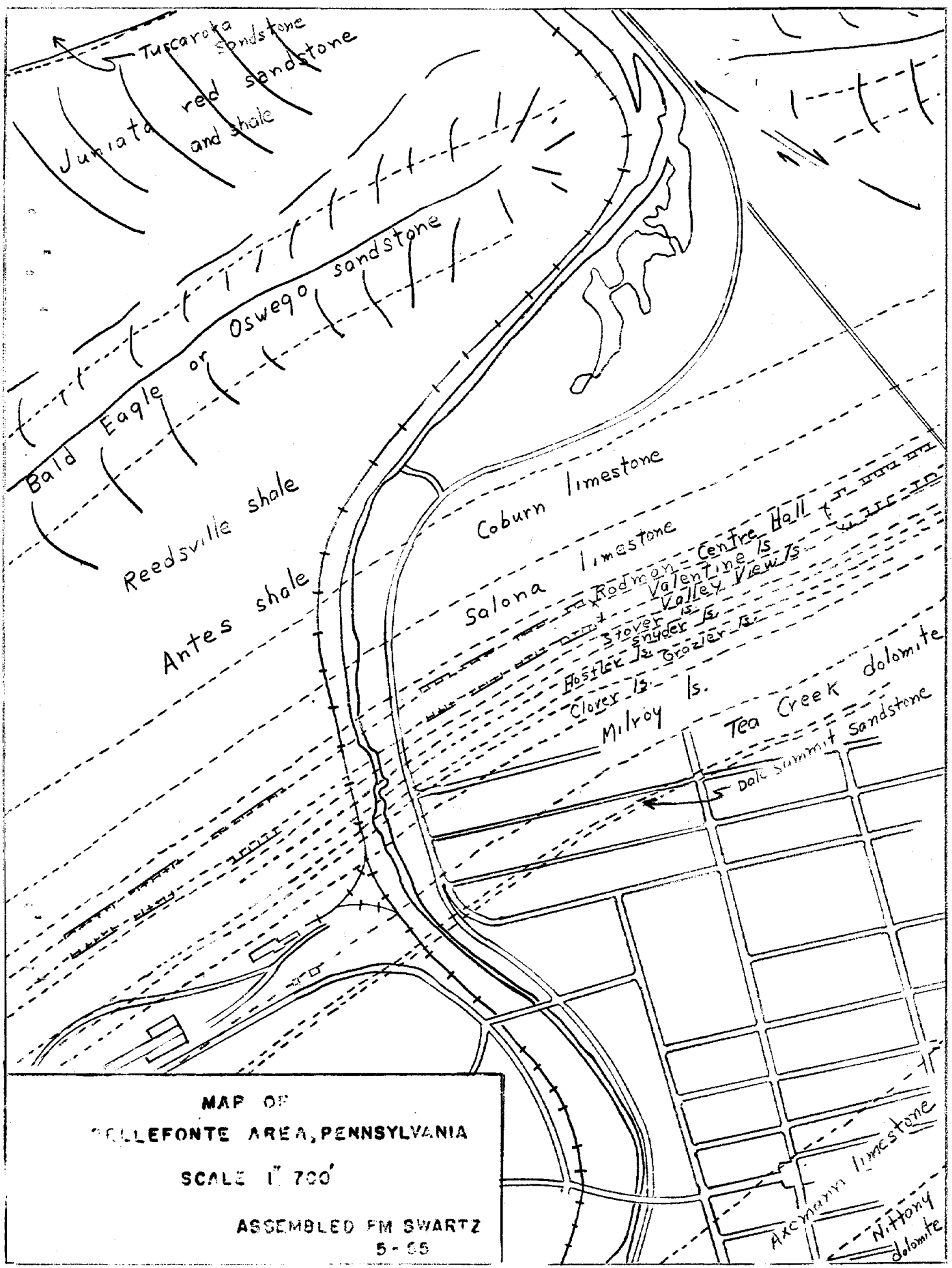
Careful stratigraphic studies of local rock sequences and of their progressive lateral changes, using critical lithologic techniques aided by petrographic and chemical work, will continue to contribute to knowledge of the carbonate rocks of the region, and to understanding of the tectonics and geography of sedimentation as well to potentialities for economic use. Critical reinvestigations are needed of many of the fossils of the area, and microfossils also offer promise for improvements in interregional and intraregional understanding and for paleoecologic interpretations.

- 2:20 PM. Return to buses and procede to highway No. 545, using road branching to left from road of entry.
- 8.8 Turn right toward Bellefonte, on highway No. 545.
- 9.0 Stonehenge limestone, dipping gently toward southeast as anticlinal axis is being approached.
- 9.7 Valley of Spring Creek on left.
- 9.0-10.0 Uppermost Mines dolomite in area of axis of Nittany Valley anticline, between grounds of Keckler Chevrolet Company on left of road and of Dan Grove DeSoto Company on right.
- 10.4-10.6 Highway curves right toward Bellefonte with high roadside cuts in Nittany dolomite; there is marked steepening of dip in this limb of the asymmetrical Nittany Valley anticline.
- 10.8 Entering outskirts of Bellefonte; some exposures of Nittany dolomite.
- 11 Continue through intersection at stop light.
- 11.3-11.4 Cross Logan Branch, then cross railroad tracks and keep lefthand fork of road.
- 11.5 Big Spring on left supplies water for Bellefonte; it has a reported flow of 14,600 gallons per minute, and is located in the belt of outcrop of the Axemann limestone.
- 11.5½ Big Trout Inn on right; there are large trout in protected waters of Spring Creek on left below highway.
- 11.6 Straight across intersection.
- 11.7-12.1 Coffee Run dolomite, giving place to Tea Creek dolomite at about 12.0½ miles.

12.1 STOP 2: 30 minutes. Leave buses at stop sign at intersection with highway from center of Bellefonte. Buses will be met farther north at 12.5 miles.

Exposures of formations from the Tea Creek dolomite to Antes shale will be examined in ascending order. For details of the lithologic and faunal features, refer to the introductory discussion for the trip.

Scattered exposures of Tea Creek dolomite are seen just south of the intersection, and show the dololutitic character of the rock, and the light yellowish gray, gash-bearing weathered surfaces. The next higher "tiger-striped" Milroy limestone is concealed. More or less calcilutitic thin-bedded layers of the Clover limestone, weathered with yellowish gray earthy surfaces, are partially exposed at entrance to a side road about 500 feet north of the intersection, in contact on north side of side road with Grazier limestone showing an excellent development of the characteristic "worm-eaten" surfaces. The Hostler limestone is mostly concealed. The Snyder limestone is well exposed, and shows beds with abundant Tetradium, as well as thin-bedded ripple marked beds just north of a partially walled up concealed interval. The Stover limestone is fully exposed, and in the higher parts of the road cut shows the "worm-eaten" pits associated with the argillaceous-dolomitic streaks and mottlings. The first prominent yellowish clayey bands are bentonite beds E and D of Rosencranz. Bed E was used by Kay to define the base of the Valley View limestone; according to work by Rones this bed is continuous with bentonite F, 20 feet below the top of the type Stover at Union Furnace, 30 miles southwest of Bellefonte; widespread occurrence of Stover-type beds above bed E-F warrants upward revision of the base of the Valley View limestone. There are traces of bentonite beds C and B. Only a few small exposures of Valentine limestone are visible at the roadside, in line with the middle part of the old quarry northeast of the highway; excellent exposures of the Valentine will be seen at Stop No. 5. The layers do show the calcilutitic character and calcite specks of the rock, and photographs will be shown illustrating the character of the rock in thin-section. There are good views of the Warner Company plant and old quarries southwest of the highway; the Warner Company has extended a heading underneath the creek at depth. The Tusseyville limestone is well exposed; small strike-slip faults at the top of the cut are offset toward the southeast on their northeasterly side, in accord with the direction of offset of a larger fault  $1\frac{1}{2}$  miles farther northeast. The lower 100 feet of the Sa'ona limestones are fully exposed, exhibiting the characteristic aphanitic texture and grayish black color; several of the bentonite beds, characteristically weathered to yellowish, clayey bands, can be seen; fossils are not abundant, but specimens of Cryptolithus tessellatus and of Brongniartella trentonensis can be found above bentonite bed No. 4. Above a concealed interval, the bulk of the Coburn limestone is excellently exposed, with highly fossiliferous coquinites favorable for collection of the Cryptolithus tessellatus fauna. The lower part of the Antes shale is exposed; some layers contain abundant Triarthrus eatoni. There is a long concealed interval to beds of



MAP OF  
BELLEFONTE AREA, PENNSYLVANIA  
SCALE 1" = 700'  
ASSEMBLED FM SWARTZ  
5-55

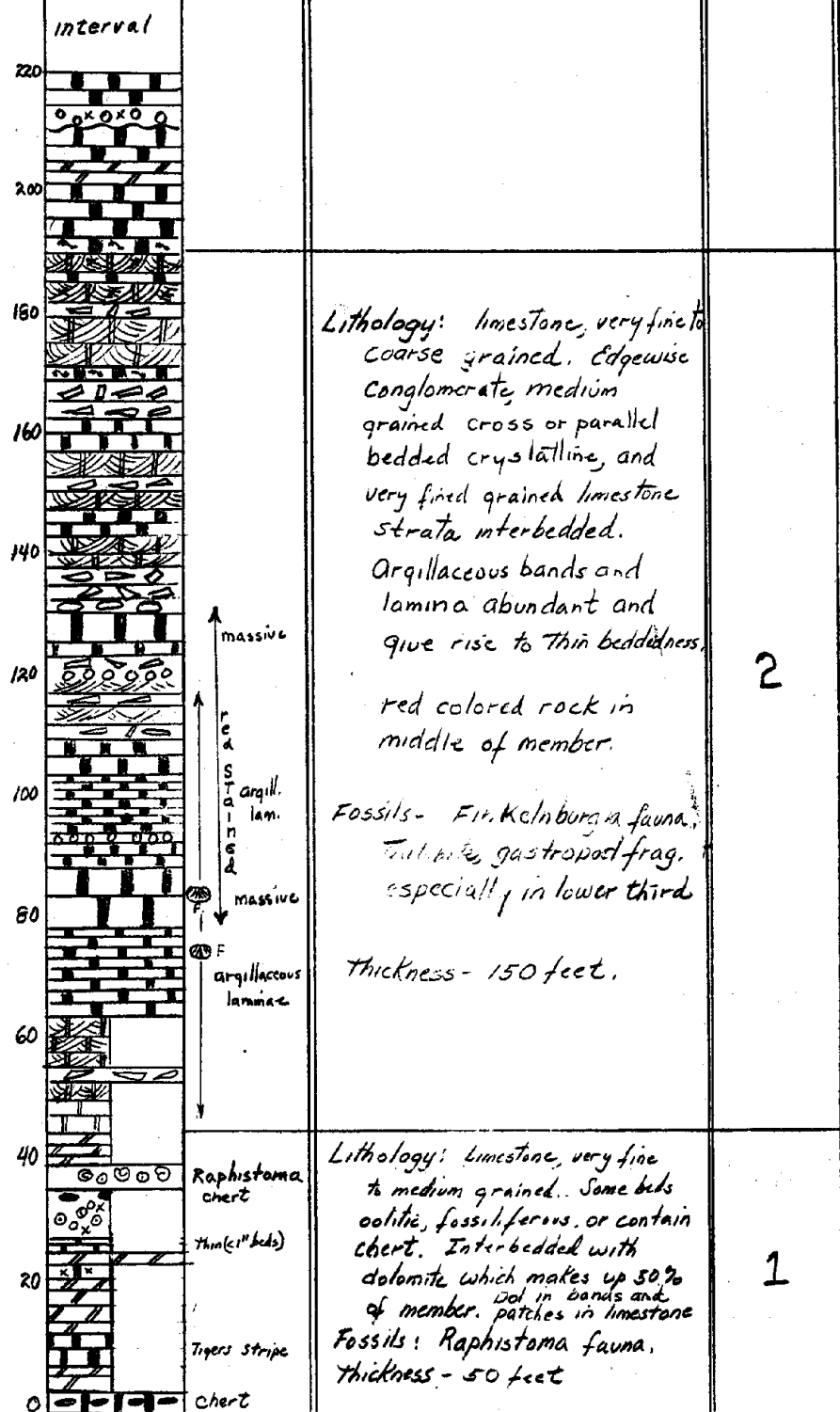
the Oswego or Bald Eagle sandstone at the entrance to Milesburg Gap. On the southwest side of the gap, the adjacent portion of the ridge in the Oswego or Bald Eagle beds is truncated for nearly a half mile at a level between 1100 and 1200 feet, apparently reflecting widening of the gap at the level of the Harrisburg peneplain.

- 3:10 Return to buses at 12.5 miles opposite exposures of Antes shale. Buses will return through town by route of entry, as far as 13.6 miles at railroad tracks.
- 13.3 $\frac{1}{2}$  Cross intersection in Bellefonte.
- 13.4-13.5 Pass Big Trout Inn and Big Spring.
- 13.6 Turn left at right angle on road to Pleasant Gap, just before crossing railroad tracks.
- 13.7 Straight through intersection at stop sign.
- 13.7-13.9 Nittany dolomite in left road cut, showing characteristic medium dark gray, pock marked surfaces, Lecanospira compacta has been reported in the lower portion of these beds.
- 13.9-14.2 Stonehenge limestone, still dipping steeply to northwest. Bellefontia collieana fauna occurs in highest of exposed ledges.
- 14.2-15.0 Mines dolomite, poorly exposed; the anticlinal axis is crossed at about 14.5 miles.
- 14.9 $\frac{1}{2}$  STOP 3: 25 minutes. Stonehenge limestone. Buses will move on to 15.6 miles.

Characters of the Stonehenge limestone will be discussed by Alan C. Donaldson, who has begun a dissertation study of the characters of the Stonehenge of the region, and the manner in which the formation changes thickness and locally disappears. To date, Mr. Donaldson has recognized the following five members of the Stonehenge of the Axemann section, given in descending order; in part these members appear to be traceable to other sections farther to the southwest in Nittany Valley.

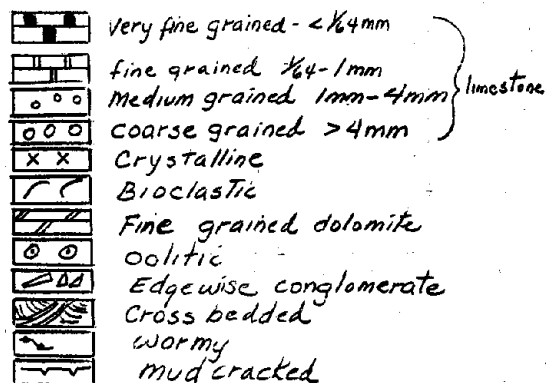
Member 5. Limestone, aphanitic to coarsely crystalline, in part oolitic and very fossiliferous; there are some zones of flat-pebble limestone conglomerate, and some  $\frac{1}{2}$ -foot to 1-foot interlayers of finely crystalline, medium-gray dolomite. Bellefontia collieana fauna with Hystericurus aff. conicus, Eccliomphalus multiseptarius, Palaeacmaea sp. 40 feet

Member 4. Limestone, aphanitic to coarsely crystalline, with irregular dolomitic streaks and bands and some thin argillaceous laminae; there are some layers of flat-pebble limestone conglomerate and several  $\frac{1}{2}$ -foot to 1-foot interlayers of finely crystalline, light gray dolomite. Fossils rare. 50 feet



## MINES

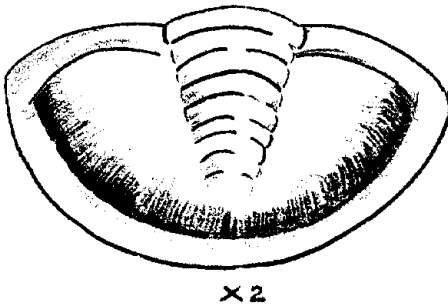
## LEGEND



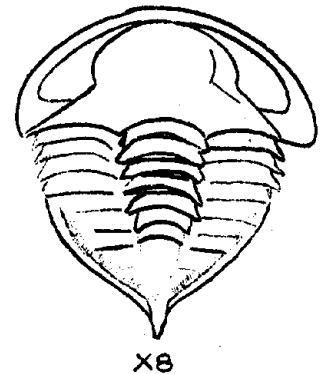
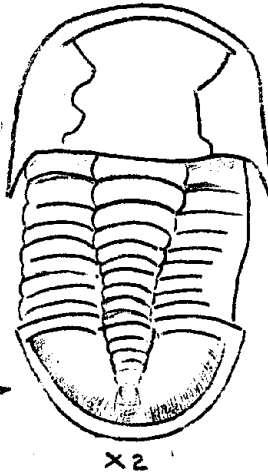
## F-17

THICKNESS		DIAGNOSTIC FEATURES	MEMBER
		NITTANY DOLOMITE	
500		Lithology: Oolitic, very fossiliferous limestone, medium dark gray, very fine to coarse grained, with 1/2-foot interbeds of fine crystalline dolomite medium light gray to dark gray weathering buff and red gray, respectively.	5
480		Fossils: <i>Bellerophon collicans</i> and other trilobites, <i>Eccyliomphalus multiseparius</i> , <i>Palaeacimaea</i> , <i>Hormotoma</i> , Crinoid plates	
460	interval	Thickness 40 feet Bioclastic with > 40% crystalline	4
440	interval	Lithology: Edgewise conglomerate, 1" thin bedded argillaceous laminated, and fine to medium crystalline limestones interbedded.	
420	interval	1/2 foot dolomitic beds present and dolomite also in bands and patches within limestone	
400		Fossil fragments sparse Thickness 50 feet	
380	interval		3
360	interval		
340	interval		
320	interval		
300	interval		
280	interval		
260	interval		
240	interval		
220	interval		
200	interval		

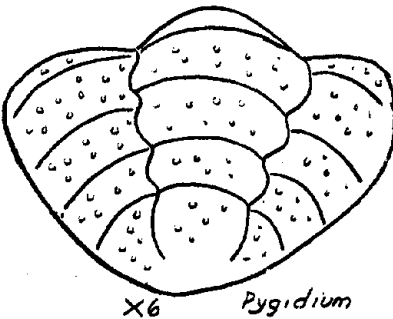
Trilobite figures from A.R. Palmer's B.S. thesis  
Stop 3 (continued)



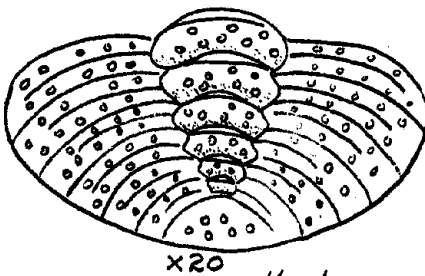
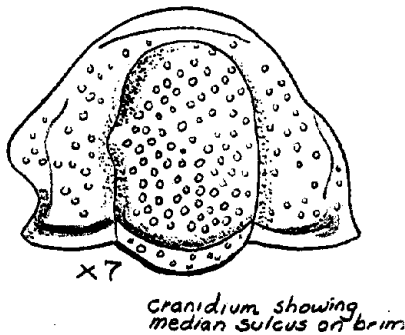
*Bellesfontia collieana*



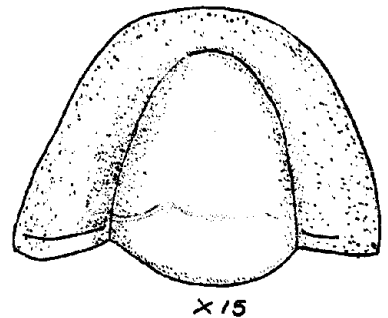
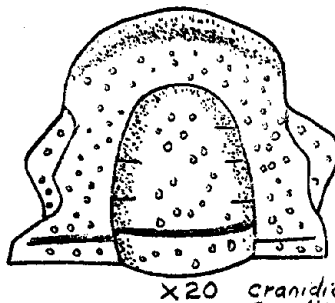
*Symphysurina acanthophora*



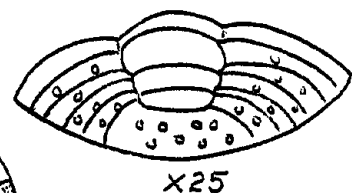
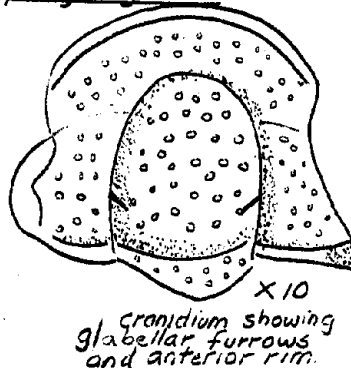
*Hystericurus interruptus*



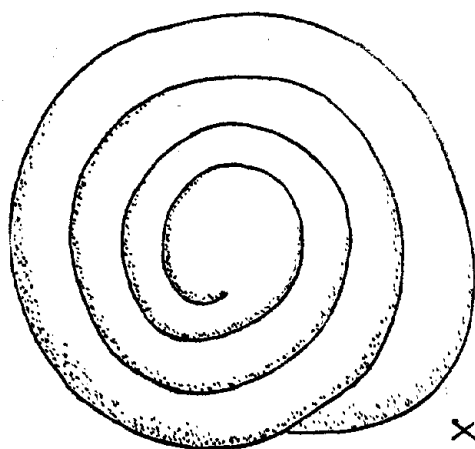
*Hystericurina platymarginalis*



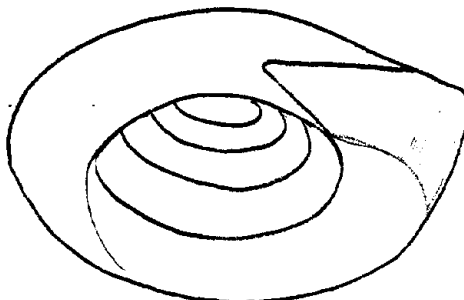
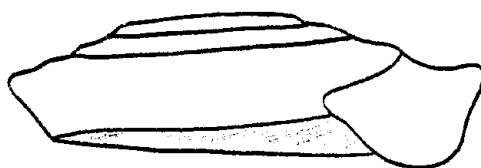
*Clelandia stonehengensis*



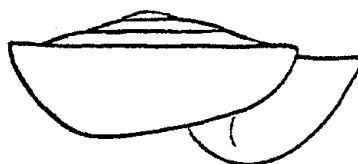
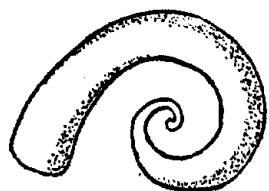
*Hystericurina conveximarginalis*



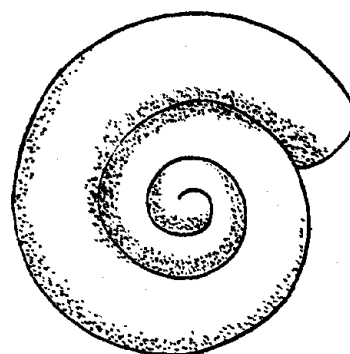
x2



Ophileta complanata

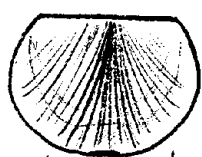


x4



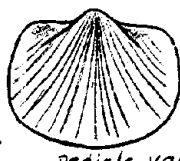
Eccyliomphalus multiseptaris

Raphistoma sp?



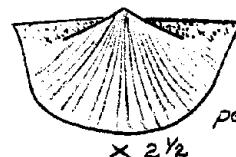
x 2½

brachial valve



pedicle valve

Finkelburgia plicata



x 2½

pedicle valve

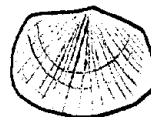
Finkelburgia buttsi



Pedicle exterior



x 2  
Pedicle interior



Brachial exterior

Finkelburgia wemplei

Member 3. Limestone, aphanitic and calcilutic, with irregular dolomitic streaks and bands; some thin interlayers are medium to coarsely crystalline, calcarenitic or oolitic; dark gray to black chert occurs in thin layers or more commonly as zones of 1-inch to 2-inch nodules;  $\frac{1}{2}$ -foot to 1-foot interbeds of finely crystalline, light medium gray dolomite are common; grains of quartz sand occur in a dolomite interlayer at 20 feet below top of member, forming a horizon that appears to be traceable to other localities; the sediments form asymmetrical cyclic sequences, typically consisting in ascending order of calcarenitic limestone, followed by dolomite then by more calcilutite. Ophileta complanata fauna; fossils generally uncommon. 210 feet

Member 2. Limestone, aphanitic to finely crystalline, with some cross-bedded calcisiltites and with numerous  $\frac{1}{2}$ -foot to 1-foot layers of flat-pebble limestone conglomerate, that is rare or wanting in next higher member; calcilutitic beds with numerous thin argillaceous laminae or bands are more abundant in lower portion; red-staining is common in middle portion. Finkelburgia sp. common to abundant in lower third. 150 feet

Member 1. Limestone, in part oolitic and containing numerous small gastropods, with interbeds of dolomite measuring as much as 10 feet in thickness and forming about 50 per cent of rock; the dolomite is finely crystalline, and weathers light brownish gray; boundary with Mines is subject to further revision. 50 feet

3:50 PM. Return to buses at 15.6 miles opposite Bellefontia collienana zone. Continue to southeast through Axemann on road to Pleasant Gap. Pass road on left at 15.6 $\frac{1}{2}$  miles, road on right at 16.1 miles. The Nittany dolomite is exposed at various places from 15.7 miles to 16.8 miles.

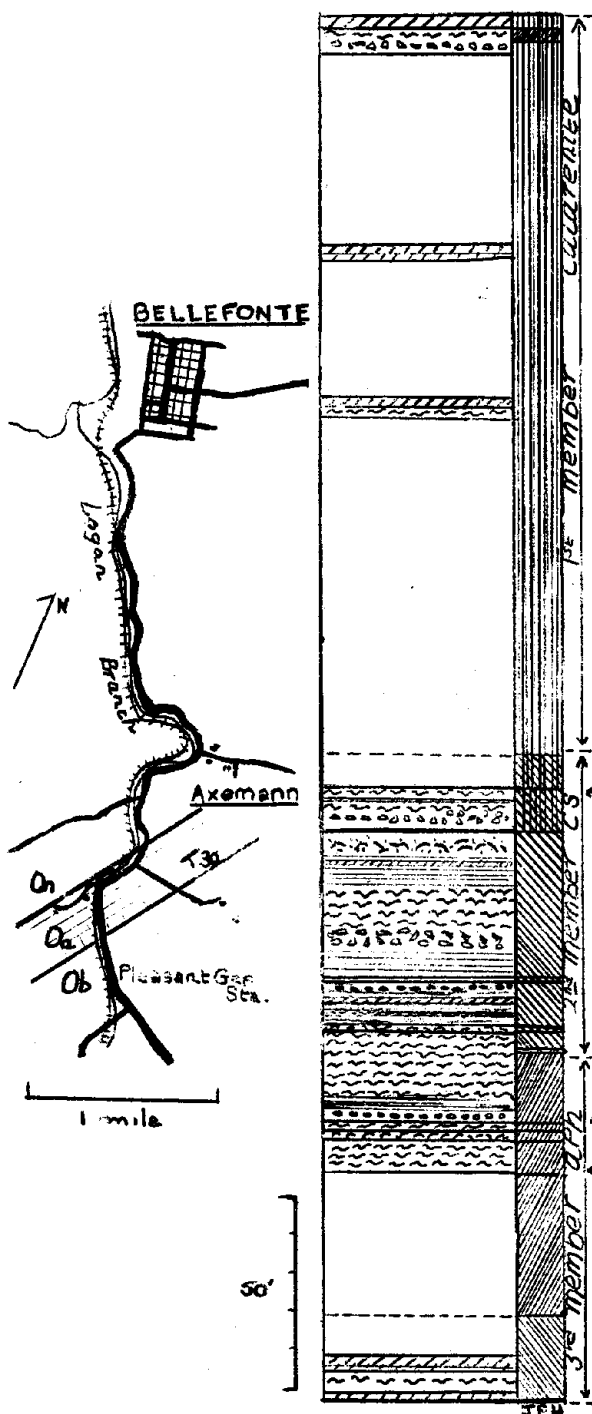
17.4 STOP 4: 20 minutes. Axemann limestone. Walk south on lane crossing creek, turn left on railroad tracks for about 200 feet and cross fence to exposures of Axemann limestone in woods.

Although this location is not very satisfactory for a visit by a large group, the opportunity will be taken to visit fossiliferous beds of the formation. Axemann stratigraphy will be discussed by J.P. Hea who has undertaken a dissertation on the Axemann intended to be comparable in scope and purpose to the Stonehenge investigation of A.C. Donaldson. In work on the Axemann at the Axemann section, Mr. Hea has tentatively recognized three lithologic members. The middle member contains three important species previously recognized in the thesis of G.R. Macaulay, namely Isoteloides triangularis which occurs in a higher zone with Maclurites affinis and species provisionally distinguished as Bathyurella paracaudatus and Bathyurella latimarginatus, which occur in a lower zone. In the latter species, the segmentation of the plural lobes of the

# AXEMANN LIMESTONE

1 MILE SOUTH OF AXEMANN, PENNSYLVANIA

## Lithology and Fossils



Coarse grained limestone with many fine grained limestone and dolomite interlayers. Edgewise conglomerates, streaked dolomite layers, laminations are common. Chert occurs parallel to bedding. Poor exposure. Data from nearby, crops.

*Isoteloides triangularis*

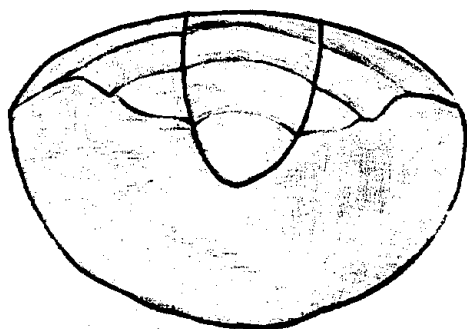
Medium grained limestone with many coarse grained limestone and dolomite interlayers. Cycles of edgewise conglomerate through dolomite. Belt, streaks, laminations and clay partings are common. This member is best exposed here.

*Bathyporellus latimarginatus*

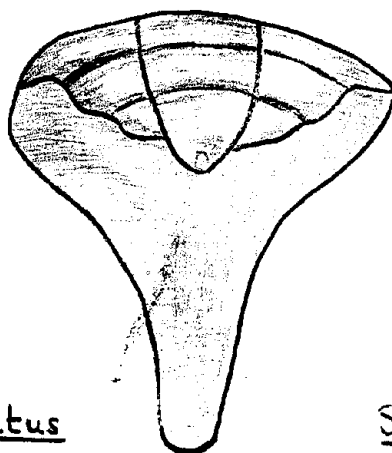
*Strophomena affinis*

Fine grained limestone with many dolomite interlayers. Fossils are common. Poor exposure.

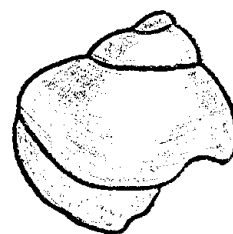
# AXEMANN L.S. FOSSILS



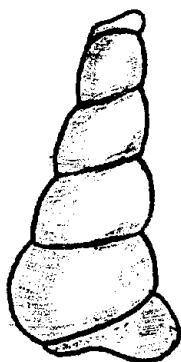
Bathytirellus latimarginatus  
Macaulay



Bathytirellus paracaudatus  
Macaulay



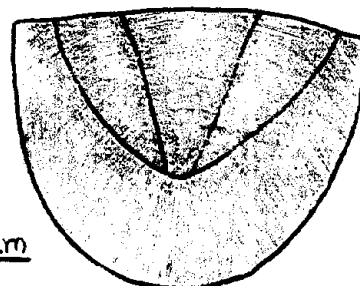
Sinuopea umbilicata



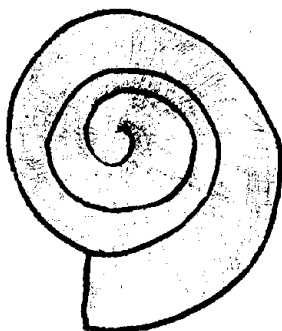
Hormotoma gracilis



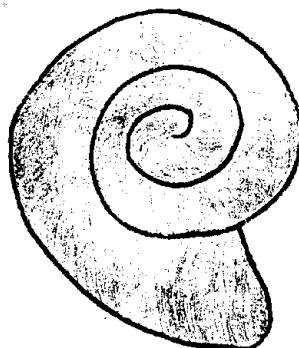
Diparalasma elongatum



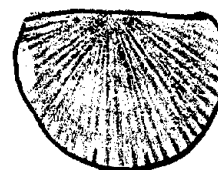
Isoteloides triangularis



Ophileta solida Ulrich



Maclurites affinis (Billings)



Tritoechia pennsylvanica

pygidium is very distinctive, aiding critical identification and use for zonation.

4:20 PM. Return to buses. Continue on road to Pleasant Gap.

18.5-18.8 Road on right; continue through underpass and enter Pleasant Gap.

19.0 Highway intersection. Turn left on highway No. 64.

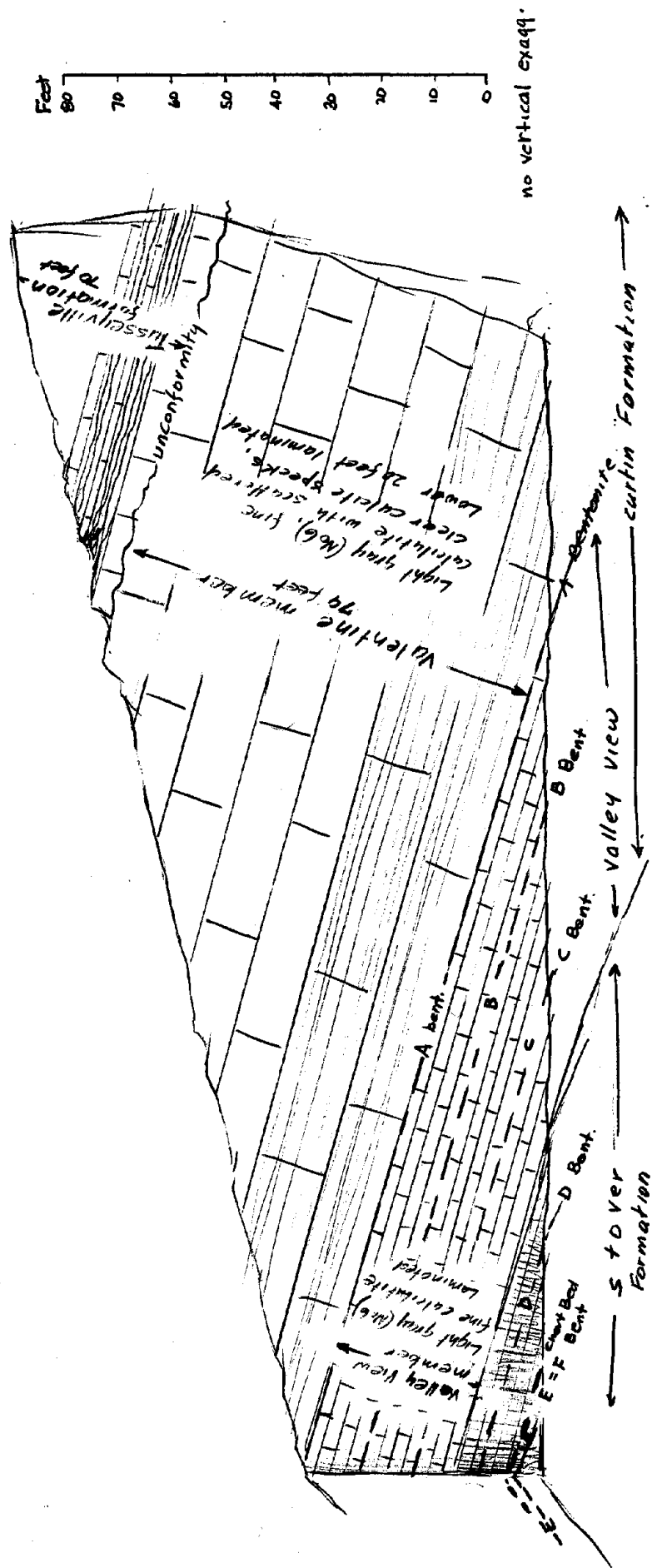
19.6 Turn right on macadam road on outskirts of Pleasant Gap.

19.7 Turn left on crushed stone road into Whiterock Quarries, and proceed to quarry face.

19.9 STOP 5: 25 minutes.

The Middle Ordovician Stover, Valley View, Valentine and Tusseyville limestones are excellently exposed in the quarry faces; their local characters and regional relations will be discussed by Morris Roncs on the basis of dissertation studies that are now being completed. Mr. Roncs began work on Ordovician limestones in Kishacoquillas Valley with G.R. Macaulay in 1951, received Survey support for mapping in parts of Brush and Penns Valleys in 1952, and subsequently has been associated with Whiterock Quarries where he has been provided with thin sections and chemical analyses of samples collected in the course of his stratigraphic studies. Both the chemical analyses and the fabrics seen in thin section have aided the investigation of the characters and correlation of the studied lithobodies.

5:00 PM. Return to buses. Return to highway No. 64, turn left and continue directly through Pleasant Gap to State College.



# RELATIONSHIPS OF SILICA DETERMINATIONS TO LITHOLOGIC BODIES AT PLEASANT GAP, PA.

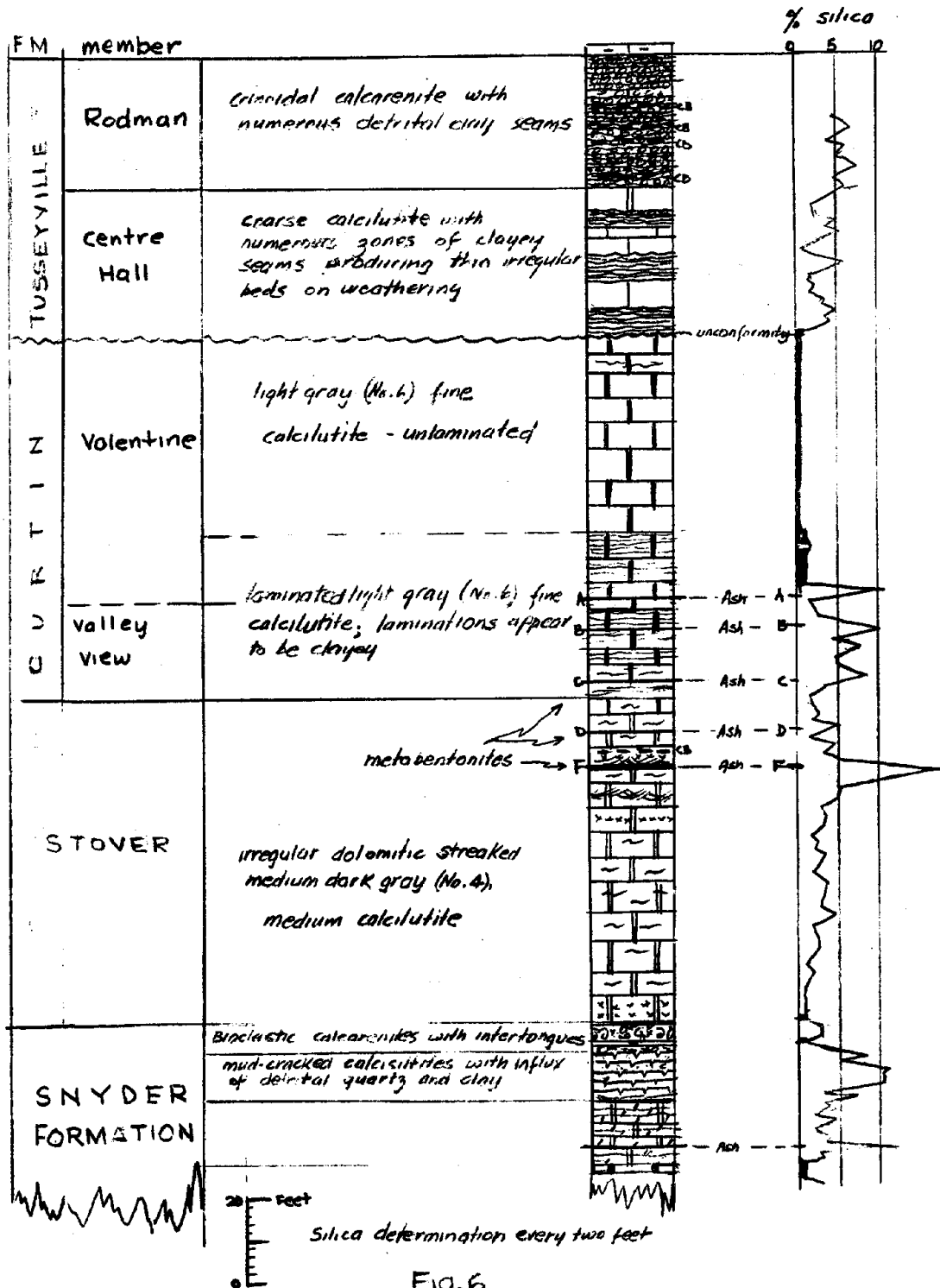


Fig. 6  
Generalized

RONES, 1955

Saturday Field Trip, May 28, 1955  
8 A.M. to 5:30 P.M.

Stratigraphy and Structure in the Ridge and Valley  
Area from University Park to Tyrone,  
Mt. Union and Lewistown

Frank M. Swartz

The Saturday Field trip offers opportunity to observe general features of the geomorphology and structure of part of the Ridge and Valley Province in central Pennsylvania, as well as to examine the predominantly detrital Upper Ordovician, Silurian and Devonian sediments that lie above the Ordovician limestones and dolomites visited during the Friday excursion.

Geomorphic features

The geomorphic pattern of elongate, narrow ridges and intervening, elongate but broader valleys, beautifully reflects the basic geologic features of the region in the manner characteristic of large areas of the folded Appalachians. The higher ridges generally follow the belts of outcrop of the Lower Silurian Tuscarora sandstone, buttressed toward the Ordovician limestone valleys by Oswego-Bald Eagle sandstone or by the partially equivalent Lost Run conglomerate. The crests of the Allegheny Front west of the Ridge and Valley area, and of Terrace Mountain and Sideling Hill within it, are formed by the Mississippian Burgoon sandstone member of the Pocono sandstone. Sandstones of the Upper Devonian Chemung and Brallier formations, and in the Huntingdon region of the Middle Devonian Hamilton group and Lower Devonian Oriskany group, hold up less elevated but nevertheless significant hogbacks. Loops or bends of the ridges reflect pitches of the folds, and in places there are offsets caused by faults. Summits of the higher ridges are comparatively level for long distances, and are indicative of former peneplains whose traces otherwise have been destroyed long since by dissection. As a rule the ridges or shoulders formed by the Upper Ordovician sandstones and conglomerates have been lowered below the levels of the Tuscarora sandstone, and have been cut by more numerous gaps. Some of the lower hills appear to reflect the level of the Valley Floor or Harrisburg peneplain that truncates hilltops of the limestones of Nittany Valley, but others rise to higher levels. Incised meanders are beautifully developed along some streams, notably along Raystown Branch of the Juniata River west of Terrace Mountain, and less extensively along Penns Creek where it cuts through the Seven Mountains.

There is some reason to postulate that special features of the bedrock at two of the stops were developed largely during past stages of the geomorphic history of the region. At stops 1A - 1B, beds of the Oswego and Juniata formations of Bald Eagle Mountain are subvertical as the highest point on the highway is approached from the southeast, whereas the Tuscarora quartzite sandstone at the summit of the steep northwesterly slope of the mountain is generally overturned, dipping to the southeast at angles of around 30 to 45 degrees. This same relationship is found in crest-forming Tuscarora beds as compared to subvertical adjacent formations in quarries on Bald Eagle Mountain 5 miles to the southwest above Port Matilda; on Dunning Mountain south of Claysburg, Pennsylvania; and with change in the formational pattern at Woodstock Gap at the summit of the western ridge of Massanutten Mountain in Virginia. It is suggested that in each of these instances the change in dip of the resistant beds at the summit of the mountain slope may represent creep or slump of strong rock ledges that are not readily removed by erosion, and that have been subjected along with their shaly partings to long continued weathering while partial peneplains were being developed at lower altitudes.

Deep weathering is reflected by chemical rather than structural changes in the Rochester and Rose Hills shales and Keefer sandstone at Stop No. 5. The Rochester shale here is tan colored with rose-colored tints, as compared to the dark gray color of the same shales where freshly exposed 6 miles to the north along Little Juniata River at levels 300 feet lower in altitude, and there are only a few clayey traces of the 2-inch to 6-inch interlayers of limestone that are common at the latter locality. Similar leaching and oxidation is found in these beds at various other places where they are close to the horizon of the Harrisburg peneplain. Such deep weathering may have been accomplished in large part in Tertiary rather than Pleistocene or Recent time.

#### General structure of the area

From the structural point of view, the course of the trip cuts almost directly across Appalachian folds for the 30 miles airline distance from Tyrone to Mt. Union. Wide Nittany Valley follows the higher part of the anticlinorium of the Nittany Valley Arch, but is subdivided to the south of the line of the trip by synclinal Brush and Canoe Mountains. The broad valley region from Tussey Mountain past Huntingdon and around the tip of Terrace Mountain to Stone Mountain, is eroded in the Broad Top synclinorium where it is deep enough to carry the Tuscarora sandstone below the levels of erosion. Stone and Jacks Mountains near Mt. Union result from reemergence of the Tuscarora sandstone in the axial portion of the anticlinorium of Jacks Mountain and Kishacoquillas Valley, in the region of southwestward plunge where the structure is simplified and lowered in altitude.

Northwestward from Lewistown, the route retraverses the same three major structures in reverse order. The anticlinorium of Kishacoquillas Valley is here at higher levels, is more complex, and is surfaced by the broad, Ordovician limestone farm lands of the Valley area. The northeasterly extension of the Broad Top synclinorium is narrowed and pinched, and in its deeper portion is represented by the Seven Mountains with their strongly pleated Ordovician and Silurian sandstones and shales. Leaving the Seven Mountains, the trip returns to Penns Valley which is eroded along a prong of the Nittany Valley anticlinorium.

All three of the major fold structures, and most of the larger folds into which they are subdivided, follow the general rule of the Ridge and Valley Province in that they are markedly asymmetrical, with southeastward dip of the axial planes and steepening of the northwesterly as compared to the southeasterly limbs of the anticlines. Minor folds by which weaker rocks are adjusted to the more competent beds adjoining them, as well as a few folds of larger size, do not always follow this same pattern. In Tyrone Gap in Bald Eagle Mountain, small folds in the Juniata formation that agree in nature of failure to neighboring, small-scale normal faults, have axial planes dipping to the northwest. In the upper part of the Reedsville shales near the axis of the Kishacoquillas Valley or Jacks Mountain anticline west of Mt. Union, there are small adjustment folds in which the axial planes tend to have a somewhat fan-like disposition.

One of the especially interesting structural features that will be visited during the trip is the Birmingham overthrust, at Stop No. 3, three miles southeast of Tyrone. Where exposed along tracks of the Pennsylvania Railroad on the south side of the Little Juniata River, the fault surface dips southeastward at an angle of about 15 degrees, and is overlain by Upper Cambrian Gatesburg sandstone and dolomite. Along the railroad tracks, the rocks below the fault are Middle Ordovician limestones, intensely fractured but recemented. Along the highway on the north side of the river, the fault overrides a structurally distinct block formed by a somewhat overturned succession ranging from Middle Ordovician limestone to Lower Silurian sandstone. It has been divergently suggested (1) that these rocks are a slice of an overridden syncline having Silurian rocks at its axis, (2) that they are rocks first dropped in a graben and subsequently overridden by the overthrust.

In contrast to the shearing that thins out the Juniata formation in the block underneath the Birmingham overthrust, the Juniata beds at Tyrone Gap are thickened by numerous small normal faults. It is possible that these faults developed as reverse thrusts and were rotated into their present attitudes by subsequent continuation of the Appalachian folding.

## Stratigraphic Sequence

The Upper Ordovician, Silurian and Devonian shales, sandstones, conglomerates and some limestones, that will be visited in the course of the Saturday trip, and that lie above the Ordovician limestones and dolomites previously observed near Bellefonte and Pleasant Gap, are listed below together with Mississippian formations, in descending order with brief descriptions. Various special features are more extensively discussed in the account of the Itinerary.

### Mississippian System

Mauch Chunk red shale (Lesley, 1876) 200 to 400 feet on Allegheny Front, 1000 feet and more in Broad Top synclorium. Red silty shale and mudrock, some gray sandstones and subordinate limestone.

Loyalhanna limestone (Butts, 1904) 40 feet thick on Allegheny Front southwest of Tyrone; not recognized in Broad Top synclorium. Highly arenaceous, cross-bedded limestone.

Pocono sandstone (Lesley, 1876) 1000 to 1200 feet. Includes at top Burgoon sandstone member (Butts, 1904) 300 to 400 feet, making crests of Allegheny Front and of Terrace Mountain and Sideling Hill; underlying interbedded sandstones and shales are cyclic at Horse Shoe Curve section, beginning with sandstones that rest on sharp erosion surfaces and grade upward into shales that in a few instances contain brackish water faunas. Patton red shale occurs in upper part of the shale and sandstone member in area west of the Allegheny Front.

### Devonian System

#### Upper Devonian series

Catskill red beds (Mather, 1840) 2000 to 2500 feet. The term Hampshire red beds (Darton, 1892) has been used in some reports to emphasize the view that the Upper Devonian red beds of the Allegheny Front and Huntingdon region are wholly younger than the type Catskill red beds of the Catskill Mountain region. Consists dominantly of grayish red cross-bedded micaceous sandstone and silty mudrock and shale, with subordinate grayish green intercalations. Fossils generally are rare, although a few ostracoderm plates may be found, and Chemung fossils occur in some basal beds.

Chemung shale and sandstone (Hall, 1839) 2500 to 3500 feet. Gray shale and interbedded sandstone, weathering yellowish brown; there are some enrolled slump structures known as "stormrollers"; in Huntingdon area, beds in upper 1000 feet are largely reddish brown or chocolate colored, foretelling their eastward intergradation into Catskill red

beds; Butts estimates that Catskill-Chemung boundary probably drops about 500 feet in stratigraphic horizon from the western limb to the eastern limb of the Broad Top synclinorium. In the Huntingdon quadrangle, Butts mapped following members for considerable distances: Saxton conglomerate member (Butts, 1918; previously identified by I.C. White with Lackawaxen conglomerate of Pike County) 100 feet of sandstone shale and some conglomerate, 800 to 1300 feet below top of Chemung; Allegrippus sandstone member (I.C. White, 1885) 50 feet, 1400 feet above Pine Ridge member; Pine Ridge sandstone member (Butts, 1918) 50 feet, 30 to 50 feet above base of Chemung. Butts also states that there are other locally developed conglomeratic beds in the area, and notes occurrences 400 feet below the Allegrippus and 100 to 500 feet above the Saxton. The Chemung shale is characterized by the Cyrtospirifer disjunctus fauna, the numerous species also including Platyrachella mesacostalis, Tylothyrus mesastriata, Atrypa reticularis, Atrypa hystrix, Schuchertella chemungensis, Dauvillina cayuta, Productella lachrymosa; Cariniferella tioga is a distinctive species of the lower portion, especially along the Allegheny Front.

Brallier shale (Butts, 1918) 1400 to 1800 feet; micaceous silty shale and some interbedded fine-grained gray sandstone; at base is Stone Creek sandstone member (Swartz, ms.) 100 feet, which produces Stone Creek Ridge, the first pronounced hogback east of Huntingdon, and appears to be continuous with the fine-grained sandstone and siltstone that produces the first line of hogbacks on the northwest side of Bald Eagle Creek in Bald Eagle Valley northwest of State College. As compared to the overlying Chemung shale, the Brallier shale tends to be more uniform, containing fine silt and mica without the sandstone interbeds that tend to become common in the Chemung; in practice, the separation has been made in the field by use of the first appearance of the abundant fossils of the Cyrtospirifer disjunctus zone. The Brallier shale is comparatively unfossiliferous; Pteridichnites biseriatus, which is perhaps the least uncommon fossil, has been interpreted as some type of trail. There are a few pelecypods and rare goniatites.

Harrell shale (Butts, 1918) 250 feet; in lower part is Burkett black shale member (Butts, 1918), grading upward into soft gray shale that becomes somewhat silty in upper part as it approaches Stone Creek sandstone member of Brallier. Styliolina fissurella is fairly common; in lower part especially are pelecypods of the Buchiola retrostriata fauna, and there are some rare goniatites.

## Middle Devonian series

Tully limestone (Vanuxem, 1839); 20 feet of argillaceous limestone, clearly equivalent to Tully limestone of wells of the Leidy and Benezette gas fields and of various nearer test drill holes, occurs in Bald Eagle Valley near Milesburg northeast of Bellefonte, directly beneath the Burkett black shale. The limestone has not been observed in the Huntingdon region, and may be replaced by shale in that area. In the Milesburg area, the limestone is fossiliferous, containing Phacops rana, Proetus rowei, Greenops sp. (new), Atrypa spinosa and other fossils; Hypothyridina venustula has not been discovered at this locality.

Hamilton group (Vanuxem, 1840) 1000 to 1400 feet; includes Mahantango shale (Willard, 1935), the gray to olive green Hamilton shale of many reports, 800 feet in Bald Eagle Valley and 1200 feet near Huntingdon, underlain by Marcellus black shale (Hall, 1887) 200 to 300 feet. The Mahantango shale is weak and generally eroded to the general level of the valley floor in Bald Eagle Valley; near Huntingdon and Lewistown it contains several siltstone and sandstone beds that cause some increase in resistance to erosion and that reflect the development toward Perry County and Harrisburg of the ridge-forming Montebello sandstone (Claypole, 1885). Contains the typical Tropidoleptus carinatus, Mucrospirifer mucronatus, Phacops rana, Greenops boothi fauna, with Pustulina pustulosa in upper beds. The Marcellus beds are dominantly fissile black shale, with a few thin interlayers of limestone and some calcareous concretions. Fossils are rare; a few specimens of Leiorhynchus limitare have been reported.

Onondaga limestone (Hall, 1839) 125 feet, including Selinsgrove limestone member (I.C. White, 1883) 35 feet, above, Needmore shale member (Willard, 1939) 90 feet, below. The Selinsgrove limestone is argillaceous, weathering buff and more or less earthy; the Needmore shale is calcareous, gray to more or less black when fresh, generally weathering tan colored and containing some interlayers of argillaceous limestone. Fauna includes Odontocephalus selenurus, Phacops cristata; ostracodes are numerous in some layers, and as described by Swartz and Swain can be used to distinguish 3 to 4 zones within the formation in central Pennsylvania. The Onondaga Needmore beds rest with sharp contact on the summit of the underlying Ridgeley sandstone, and sand grains evidently derived from the Oriskany surface tend to be reworked and incorporated in the basal several inches of the Needmore.

## Lower Devonian series

Oriskany group (Vanuxem, 1839) 175 to 250 feet, includes Ridgeley sandstone (C.K. Swartz, 1913) above, 50 to 125 feet; Shriver siliceous limestone (C.K. Swartz, 1913) 125 feet, below. Ridgeley sandstone consists of clean quartz sand, in some areas and horizons highly calcareous when weathered. This is the Oriskany sandstone of the deeper gas fields of

northern and western Pennsylvania; it is extensively worked for glass sand in the vicinity of Mapleton east of Huntingdon; it is the source of an artesian well obtained at the Owens Corning Fiberglass plant in Huntingdon; it contains the Costispirifer arenosus, Acrospirifer murchisoni, Hipparionyx proximus fauna of the Oriskany sandstone of New York; other species include Rensselaria ovoides vars., Meristella lata, Plethorhynchus speciosa. The Shriver limestone is highly siliceous, becoming silty in upper part; it weathers into lightweight, punky blocks, suggestive of weathered impure chert; some of silica is derived from sponge spicules, and parts of the rock contains small percentages of collophane. The fauna includes Chonetes hudsonicus, Metaplasia plicatus, Orbiculoidea jervensis, and numerous ostracodes including especially Thlipsura confluens, Craterellina robusta, Thlipsurella seccoclepta, T. ellipsoclepta.

Helderberg group (Conrad, 1839) 60 feet, including Mandata shale (F.M. Swartz, 1939) 30 feet, underlain by New Scotland limestone (Clarke and Schuchert, 1899) 20 feet, and Coeymans limestone (Clarke and Schuchert, 1899) 10 feet. The Mandata shale is distinctly less siliceous and blocky than are overlying beds of the impure Shriver limestone; the New Scotland limestone is cherty, and contains Eospirifer macropleurus, Delthyris perlamellosa and other characteristic fossils; it is suggestive lithologically of the Kalkberg member of the New Scotland of New York; the Coeymans limestone is crystalline and crinoidal, contains the characteristic Gypidula coeymanensis fauna, and has at its base at its base at many places small fragments of the upper Keyser limestone upon which it rests with a sharp and apparently disconformable contact.

## Silurian System

### Cayugan series

Keyser limestone (Ulrich, 1911) 125 to 175 feet. At top, Paintersville limestone member (Swartz, ms) 40 feet, consisting of thinly laminated limestones, some thicker interbeds; underlain by Hollidaysburg limestone member (Swartz, ms) 50 feet, thin- to medium-bedded, locally somewhat cherty limestone; and Mt. Rock limestone member (Swartz, ms) 50 feet, composed dominantly of lumpy or nodular limestone with some interbeds of crinoidal limestone. Chonetes jerseyensis fauna in lower portion; other especially important fossils include Merista typa, Gypidula prognostica, Camarotoechia gigantea, Rensselaerina mutabilis, and at some localities Kalysites catenularia var. and other corals.

Tonoloway limestone (Ulrich, 1911) 700 feet at Mt. Union, where Swartz (1934) recognized in descending order, upper purer limestone member, dolomitic limestone member, middle limestone member, mudrock and argillaceous limestone member, and lower limestone member. In middle limestone member especially there are cyclic deposits, with basal fossiliferous limestones in which are found Hindella congregata, and new Zygobeyrichia dorsocristata which ranges southward in a well defined zone

into the Sneedsville limestone of Tennessee. The mudrock beds reflect northward and northeastward increase in clayey material.

Wills Creek shale (Uhler, 1905) 450 feet; consists of cyclically deposited argillaceous dolomitic limestone, laminated argillaceous limestone, and calcareous gray mudrock weathering yellowish green, the mudrock in part grayish red or red-splotched and then representing tongues from portions of the Bloomsburg red beds into which the Wills Creek intergrades toward the southeast and east. There are a few small cubical vugs possibly left from solution of halite crystals. Fossils are rare; there are some species of Leperditia, and toward the west Zygobeyrichia ventricornis is found in basal layers.

Bloomsburg red beds (I.C. White, 1883) 50 to 100 feet, containing in middle part Lucy School siltstone member (Swartz, ms) 20 to 30 feet. Upper and middle parts consist of calcareous grayish red mudstone breaking into small hackly fragments; Lucy School member consists of upper and lower bodies of arenaceous, grayish red siltstone, breaking into coarser hackly fragments, separated by about 5 feet of red mudstone based by greenish gray calcareous shale; this member is persistent from the type area at Mt. Union to Altoona on the west and Lewistown and Mifflintown on the northeast, maintaining the triplicate structure over much of the area.

#### Niagaran series

McKenzie shale and limestone (Ulrich, 1911), 350 feet; includes at Mt. Union upper shale and limestone member, 70 feet, containing Kloedenella gibberosa ostracode zone; Rabble Run red calcareous mudrock member (C.K. Swartz, 1923) 70 feet; lower limestone and shale member 210 feet, thin-bedded generally aphanitic limestone with minor occurrences of flat limestone pebble conglomerate, and containing zones of Kloedenella nitida, Velibeyrichia moodeyi, Whitfieldella marylandica with Kloedenella cornuta.

Clinton group (Conrad, 1839) 855 feet, including in descending order Rochester shale (Conrad, 1839) 40 feet; Keefer sandstone (Ulrich, 1911) 40 feet; Rose Hill shale (C.K. Swartz, 1923) 700 feet; Castanea sandstone (F.M. Swartz, 1934) 75 feet. The Rochester shale is dark gray, calcareous shale with numerous interlayers of highly fossiliferous medium gray medium crystalline limestone; it contains the Dalmanites limulus, Stropheodonta proutyi, Stegerhynchus neglecta, Drepanellina clarki fauna. Keefer sandstone includes upper, quartzose, somewhat calcareous sandstones containing crinoid fragments, underlain by calcareous argillaceous and arenaceous rock containing Schuchertella subplana and other fossils. The Keefer sandstone was termed the "Ore Sandstone" by the members of the Second Geological Survey of Pennsylvania because of associated, thin beds of iron ore that were worked at various places in Pennsylvania during the 19th century. The Rose Hill shale is seen

at the outcrop as an olive gray and in part chocolate-colored shale, containing a few thin interlayers of fine-grained sandstone or quartzose siltstone, and in the upper portion some thin interlayers of highly fossiliferous limestone. Some thin interlayers of iron ore have been discovered in it in Pennsylvania, but none are to be seen in the comparatively complete exposures at Mt. Union except for several thin layers just beneath the Keefer sandstone. The Rose Hill shale is characterized by Coelospira hemispherica, changing in upper beds to Coelospira sulcata; by Chonetes aff. C. novascoticus and Liocalymene clinton; six ostracode zones are based primarily upon Mastigobolbina typus, Bonnemaia rudis, Mastigobolbina modesta, M. lata, Zygobolba bimuralis, Z. decora and Z. anticostiensis. The Castanea sandstone in a sense represents intergradation from the Tuscarora quartzitic sandstone into the Rose Hill shale; it contains some layers of shale and some of quartzitic sandstone, but it is characterized especially by grayish red and greenish siltstone and fine-grained sandstones that abound with Scolithus tubes, the bedding surfaces covered with lumps that appear to be castings from the tubes. The red siltstones and fine-grained sandstones can be found at many places on the mountain slopes and provide an excellent key to the boundary between the Clinton and Tuscarora sediments.

#### Medinan series

Tuscarora quartzite or quartzitic sandstone (Darton, 1896) 400 to 500 feet. The Tuscarora is characterized by dominance of beds of clean quartz sand, generally well cemented by quartz overgrowths; there are numerous thin partings of somewhat silty gray and in part grayish red shales, grading into argillaceous siltstone, the shale and siltstone forming 10 per cent and more of the rock and increasing westward; the quartz sand and clay and silt were however exceptionally well separated during sedimentation so that sandstones where deeply weathered on the mountain slopes are used for ganister rock in the manufacture of silica brick, and have reported compositions of as much as 98 per cent  $\text{SiO}_2$ . In most parts of the Tuscarora the sandstones are extensively cross-bedded, with amplitudes of  $\frac{1}{2}$ -foot to 2 feet; some beds are laminated parallel to the general bedding and then commonly are extensively ripple-marked, at least in part by symmetrical ripple mark; some bedding surfaces show numerous pits left by shale chips, as much as 2 to 4 inches in greatest diameter; some layers bear numerous small limonitic specks at distances of around  $\frac{1}{8}$ th inch apart, possibly from the weathering of ankerite. Shelly, definitely marine fossils are not known; there are eurypterid fragments in some of the shaly interlayers; more common are Arthropycus alleghaniensis, subhorizontal worm burrows, and Scolithus tubes, seen both as tubes vertical to the bedding and as pits of the bedding surfaces.

## Ordovician System

## Cincinnatian series

Juniata red sandstone and shales (Darton, 1896) 1200 to 1500 feet; including in descending order Run Gap sandstone member (Swartz, ms) 100 to 260 feet; Plummer Hollow red mudstone and sandstone member (Swartz, ms.) 400 to 600 feet; East Waterford red sandstone member 500 to 800 feet. The Run Gap member named from Run Gap in Tuscarora Mountain is widely developed through central Pennsylvania, is formed of comparatively quartzitic red sandstones, and at many places occurs at or near the crests of the ridges held up by the Tuscarora sandstone; it is finer grained, less quartzose and not typical in exposures along Bald Eagle Mountain. The East Waterford graywacke sandstone makes up the bulk of the Juniata formation at East Waterford Narrows in Tuscarora Mountain, selected by Swartz (ms) to be the type section of the Juniata formation; westward the upper portion of the East Waterford sandstone becomes finer grained, with increasing proportions of red siltstone and mudstone, and the portions in which sandstone is distinctly subordinate are being termed Plummer Hollow from the hollow of that name on the southwestern side of Tyrone Gap; the boundary between the East Waterford and Plummer Hollow members is gradational in these areas and is not well defined.

Lost Run conglomerate (Swartz, ms.) 0 to 350 feet; named from Lost Run at Lost Creek Gap in Shade Mountain; is older than Oneida conglomerate of New York; where well developed it contains numerous subrounded to subangular, not flattened pebbles of chlorite splotted vein quartz, and of less abundant quartz-veined, in part glassy, chlorite-zone meta-quartzites and some meta-argillites; of red, gray and green jasper and more rarely of gray chert, the matrix grayish red to greenish gray graywacke sand. The conglomerate disappears westward by gradation into the Spring Mountain sandstone member of the Oswego or Bald Eagle sandstone.

Oswego sandstone (Emmons, 1846) 400 to 650 feet, also known as Bald Eagle sandstone (Grabau, 1909) from exposures at Tyrone Gap. Includes Spring Mount sandstone member (Swartz, ms.) 200 to 450 feet, above, and Centennial School sandstone and shale member (Swartz, ms.) 175 to 200 feet, below. The Spring Mount sandstone member forms the crest of the southeasterly ridge of Bald Eagle Mountain; traced into more easterly ridges it becomes finely conglomeratic and grades laterally into Lost Run conglomerate, with changes to reddish colors not coincident with the increase in size of pebbles. The Centennial School sandstone and shale is less resistant than the Spring Mount beds, and occurs on the valleyward slopes of the ridges crested by the latter member; where the Spring Mount beds are transformed to Lost Run conglomerate, the underlying Oswego sandstones are believed to correspond to the Centennial School member of Bald Eagle Mountain, although as is expectable there is

reduction in proportion of the shaly interlayers. In exposures toward Bedford County, the Spring Mountain member and in part the Centennial School member tend to be transformed to red sandstones of East Waterford type.

Reedsville shale. At top the Orthorhyncula stvensoni zone. For further description of this formation and the older strata of the region see the discussion concerning the Friday afternoon trip.

Field Trip No. 2  
 Saturday, May 28, 1955  
 8 A.M. to 5:30 P.M.

Frank M. Swartz

Petrology of the Reedsville, Oswego  
 and Juniata formations at Stop No. 1 by  
 P. D. Krynine

Departure: In buses at 8 A.M., Park Avenue northeast of Atherton Street,  
 behind Nittany Lion Inn.

Quadrangles: Bellefonte, Tyrone, Huntingdon, Mt. Union, Centre Hall.  
 For trip route, see multilith copy of assembled topographic  
 sheets, near back of Guidebook.

### Itinerary

#### Miles

- |         |  |
|---------|--|
| 0.0     | Turn right, to northwest on Atherton Street, Route 322, and<br>continue through State College to northwest.  |
| 0.3-0.4 | Stonehenge limestone, dipping about 8 degrees to southeast.<br>Beds of flat pebble limestone conglomerates are numerous.   |
| 0.6     | Cross tracks of Bellefonte Central Railroad.   |
| 0.6-1.0 | Rising or dip slope, with base of Stonehenge limestone near<br>foot of slope, Mines dolomite dipping gently southeast on<br>higher parts. Nodules of chert are abundant in the soil from<br>the Mines; many of cherts are oolitic, some are replacements<br>of heads of <u>Cryptozoa</u> . |
| 1.4     | Entering scrub forest area of the Barrens. Sandy soil from<br>the Gatesburg dolomite and sandstone is acidic, low in<br>nutrients, and dries rapidly so that the lands are generally<br>not cultivated.  |
| 2.4     | Small quarry pit in residual Gatesburg sand.   |
| 2.8     | Small exposures of Gatesburg dolomite and sandstone; minor<br>folding could be seen before cuts were sodded.   |

- 3.5 Gatesburg exposed on left at embankment of former overpass of railroad siding to Scotia iron ore pits, which were worked for sometime in the last century by Andrew Carnegie.
- 3.6 $\frac{1}{2}$  Ledges of Gatesburg dolomite, 25 feet thick, are exposed about 100 feet northeast of highway. The rock is arenaceous; flat pebble conglomerates are common in lower part.
- 4.1 $\frac{1}{2}$  Side road on left leads to Scotia ore pits.
- 4.1 $\frac{1}{2}$ -4.2  
4.3-4.3 $\frac{1}{2}$  Warrior limestone, dipping 30 degrees to southeast in southeastern limb of main part of Nittany Valley arch. There are some small reefs of Cryptozoa.
- 4.6 Cross Valley at approximate location of Birmingham fault. Road to right at 4.4 $\frac{1}{2}$  miles leads near Waddle to exposures of overturned Gatesburg of overthrust block.
- 4.6-5.6 Bellefonte dolomite beds are folded in underthrust block.
- 5.6 Cross roads. Valentine limestone can be seen in small, overgrown prospect quarry to left and beyond the crossing.
- 5.9-6.0 Reedsville shale in bank on right.
- 6.0-6.1 STOP NO. 1A: 20 minutes. Oswego or Bald Eagle sandstone, underlain by Reedsville shale and overlain by Juniata red beds. The petrology of the Reedsville, Oswego and Juniata will be discussed by P.D. Krynine.

The section as described by F.M. Swartz can be briefly summarized as follows, and will be used for comparisons with sections visited at other stops.

#### Ordovician System

##### Juniata red beds

Horizon of Run Gap red quartzitic sandstone member: sandstone, fine-grained, red, at summit of grade, not quartzitic as in more easterly sections. 100 feet

Plummer Hollow red mudrock member; mudrock, silty, red, and interbedded sandstone, red, poorly cemented. Now largely concealed. These fine-textured strata pass laterally toward east into upper part of type East Waterford beds 375 feet

East Waterford red sandstone member; sandstone and some inter-bedded silty shale or mudrock, dominantly grayish red but in part green; shale chips are numerous on some bedding surfaces; other surfaces variously show mudcracks and flow and slump markings.

550 feet

Thickness of Juniata about

1025 feet

Oswego or Bald Eagle sandstone Spring Mount sandstone member; sandstone, greenish gray, thick bedded, forming backbone of southeasterly ridge of Bald Eagle Mountain. In parts of rock, fresh exposures show abundant secondary pyritic, in minute stringers. Pebbles are very rare if not absent.

220 feet

Centennial School sandstone and shale member; sandstone, greenish gray, with interbeds of greenish silty shale.

110 feet

Apparent thickness of Oswego or Bald Eagle sandstone. The thickness small for area and perhaps reduced by faulting

330 feet

Reedsville shale; concealed, including Orthorhynacula stevensoni beds; thickness at date of measurement.

40 feet

Shale, dark gray, weathering greenish gray to tan, with some thin interlayers of siltstone and of fossiliferous limestone. Concealed.

400 feet

Thickness of Reedsville to base of exposure

440 feet

The Spring Mount member of the Oswego or Bald Eagle sandstone reflects the culmination of the Taconic orogeny, which is represented in eastern Pennsylvania by the unconformity between the Martinsburg shale and overlying Tuscarora-Shawangunk sandstones and conglomerates. Marine faunas disappeared from the area at the close of sedimentation of the Reedsville Orthorhynacula zone and did not reappear until Clinton time. The Spring Mount sandstone member coarsens eastward and becomes Lost Run conglomerate. Detritals from the Taconic uplands were brought in with diminishing size, until coarsened again by renewed uplifts that produced the Run Gap and Tuscarora sandstones.

Return to buses, and continue to summit of ridge.

- 6.4 STOP NO. 1B: Skytop on Bald Eagle Mountain. 15 minutes. Geomorphology of Allegheny Front; stratigraphy of Tuscarora sandstone and structure at the exposure.

The rocks of Nittany Valley and Bald Eagle Mountain dip north-westward beneath the strata of Bald Eagle Valley and the Allegheny Front; their horizons do not reappear until brought up to the west on the flanks of the Cincinnati arch in Ohio and to the north in New York by the rise toward the Canadian uplands. The Lower and Middle Devonian sediments occur in bottom lands adjoining Bald Eagle Creek; the first foothills of the Allegheny are formed by the basal Stone Creek member of the Brallier shale; sandstone and conglomerate beds of the Chemung shale form higher foothills; the main escarpment is crested by the Burgoon sandstone member of the Pocono formation.

The Lower Silurian Tuscarora quartzite is extensively exposed along the highway near the mountain summit. Ledges on the southeastern side of the highway near a motel are vertical, but elsewhere the beds are overturned, dipping to the southeast at angles of 30 to 45 degrees. The exposed section can be summarized as follows:

#### Silurian System

##### Castanea sandstone

Greenish siltstone or very fine-grained sandstone, red at 15 to 22 feet and 46 to 51 feet above base; 15 feet of shale at base; Scolithus tubes abundant in some layers. 75 feet

##### Tuscarora quartzite

Upper member: sandstone, quartzite, fine-grained, greenish to tannish white, with 20 to 25 per cent or more of interbedded shale and somewhat argillaceous siltstone. 105 feet

Middle member: sandstone, quartzitic, medium-grained, grayish to tannish white, in layers  $\frac{1}{2}$  foot to 3 feet, rarely 6 feet thick; cross-bedding common; interlayers of greenish and red shale form possibly 3 to 5 per cent of rock; shale chips abundant on a few bedding surfaces; Arthropycus excellent at 75 feet above base. 160 feet

Lower member: sandstone, quartzite; exposed surfaces somewhat yellowish; at top, 10 feet of arenaceous siltstone, the yellowish surface contrasting with whiter color of overlying strata. Openings of Scolithus tubes are prominent on several surfaces. Thickness exposed: 50 feet

Generally concealed, possibly 75 to 100 feet.

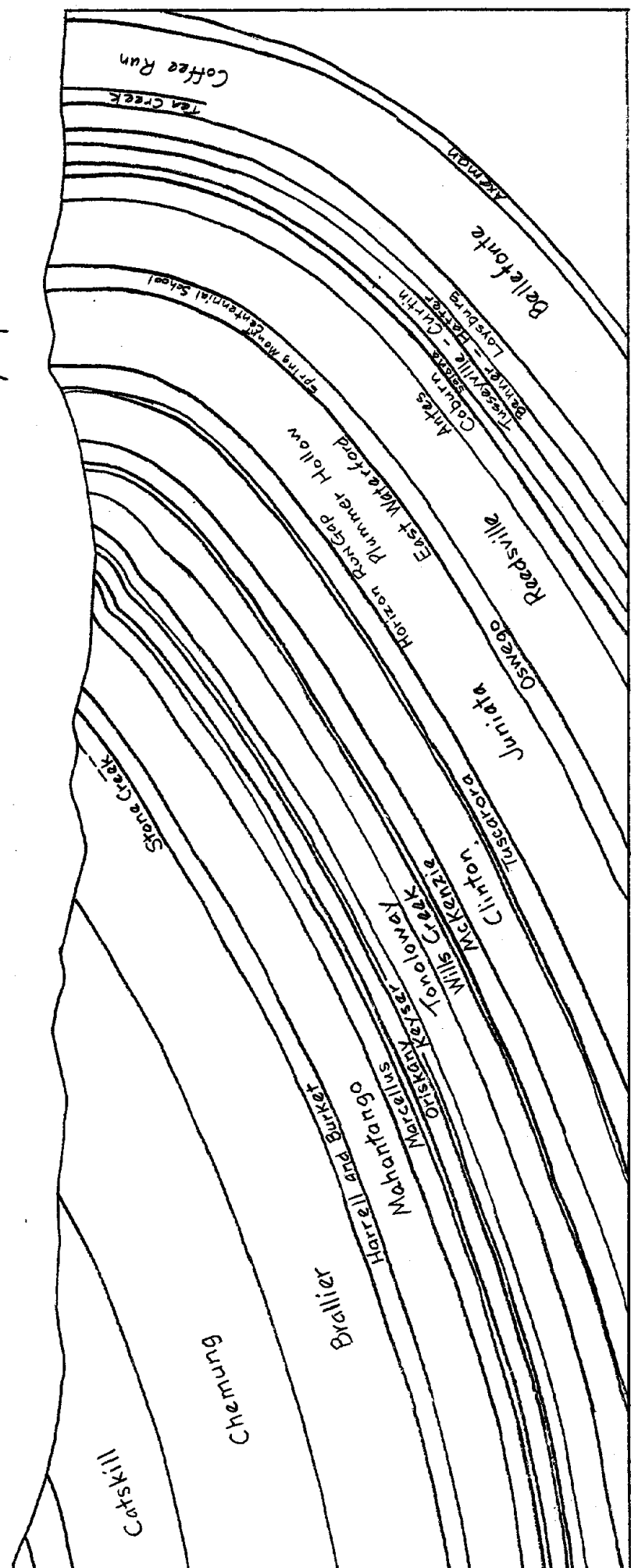
Thickness of Tuscarora possibly

400 feet

# STRUCTURE FROM SKYTOP ON BALD EAGLE MOUNTAIN NORTHWESTWARD TO THE ALLEGHENY FRONT

Bald Eagle Mountain  
at Skytop

Allegheny  
Front



In spite of the shaly partings, notable in the upper layers, the quartzite beds themselves are high in silica and are extensively used as ganister rock for manufacture of silica brick. Long weathering near the mountain summit has increased purity, and analysis of 97 to 99 per cent silica have been reported elsewhere in the region.

The Tuscarora sands appear to have been deposited in shallow but widespread waters where they became excellently winnowed over most of the area of sedimentation. Input of sediment was not too rapid to permit shifting and reshifting of the sands. Marine Shelly Faunas have never been found, although occasional abundance of worms is indicated by Scolithus tubes and Arthropycus burrows, and eurypterid fragments are found in some shale interlayers. Salinity of the waters of deposition apparently was low and factors such as acidity and possibly temperature were unfavorable for deposition of lime mud with the sand. Toward the east, the Tuscarora coarsens and tends to unite with sandstones and conglomerates that replace the Clinton Shales, forming over the region a gravel-sand-clay-subordinate limestone complex that like the Oswego-Juniata complex reflect lowering of the source region after an earlier stage of greater erosional vigor. Eastward shift in the center of sedimentation is shown by the accompanying isopachous-isolithic maps.

In the approach from the eastern side of the mountain, vertical dips persist through the Oswego and Juniata beds into the first exposures of the Tuscarora at a motel near the summit. It is possible and even probable that the overturned parts of the Tuscarora have been tilted by creep during the long period the crest has stood above the level of the Harrisburg Peneplain. Similar possibility of extensive creep of resistant quartzite layers at the summit of ridge crests can be found elsewhere along Bald Eagle and Dunning Mountains in Pennsylvania, and at Woodstock Gap in Massanutten Mountain in Virginia.

Return to buses. Continue to southwest down slope of mountain.

- 6.9                      Castanea Sandstone
- 7.0-7.1                Loose Rose Hill Shale, Coelospira hemispherica, Zygobolba spp.
- 7.6                      Bloomsburg red mudrock, deeply weathered.
- 9.0                      Turn left on highway at foot of mountain.
- 9.7-9.9                Road cuts in Harrell shale at base of Upper Devonian.
- 10.0-10.2             For next 8 miles, highway generally follows the north-
- 10.4-10.5             westerly margin of the alluvial plain of Bald Eagle Creek, close to the line of foot hills formed by the Casal Stone Creek Sandstone member of the Brallier shale. There are extensive cuts, mostly in the Harrell shale, but extending at some places into the higher Stone Creek beds, and elsewhere into the early Harrell

Burkett black shale.

- 10.4-11.6      Ganister quarry of McFeely Brick Company (Harbison-Walker) just below summit of Bald Eagle Mountain on left. Exposes overturned Tuscarora beds, steepened to about 60 degrees in deepest part of quarry. The quarry faces are high, but do not cut very far back from former surface of mountain.
- 11.3            Enter Port Matilda. Cross the highway intersection at 11.9 miles.
- 12.0-12.3, 12.4-12.6, 12.8-13.0      Highway cuts, mostly in Harrell shale.
- 13.6            To the left, Tuscarora ridge of Bald Eagle Mountain is cut by gap at possible fault.
- 14.6-14.7      Harrell shale
- 14.9            Burkett black shale
- 17.2            Highway shifts toward middle of outer belt of Hamilton shale.
- 21.0            Intersect highway to Phillipsburg. Continue southwest toward Tyrone.
- 23.7            Highway overpass above tracks Pennsylvania Railroad.
- 24.3            Low foothill ridge to left of highway is formed by Oriskany and Helderberg. Highway cuts through this low ridge at 24.9 miles.
- 25.9            Knoll to right of highway provides favorable exposures of Keyser and Tonoloway limestones.
- 26.1            Enter Tyrone. Plant of West Virginia Pulp and Paper Company on right.
- 26.9            Turn left from Pennsylvania Avenue onto Route 350 at 10th Avenue

27.0 to 27.2      Poor exposures of basal Tuscarora and upper Juniata Run Gap red sandstone and Plummer Hollow red mudstone members.

27.3      STOP No. 2 (15 minutes). Tyrone Gap separating Bald Eagle Mountain from its southwesterly continuation known as Brush Mountain. The section exposed at the gap is as follows:

Tuscarora quartzite: basal beds exposed along railroad on southwestern side of gap      50 feet.

Juniata red beds

Horizon of Run Gap red sandstone member: sandstone, dark red, a few layers of quartzite, and some interlayered red shale, largely concealed.      125 feet.

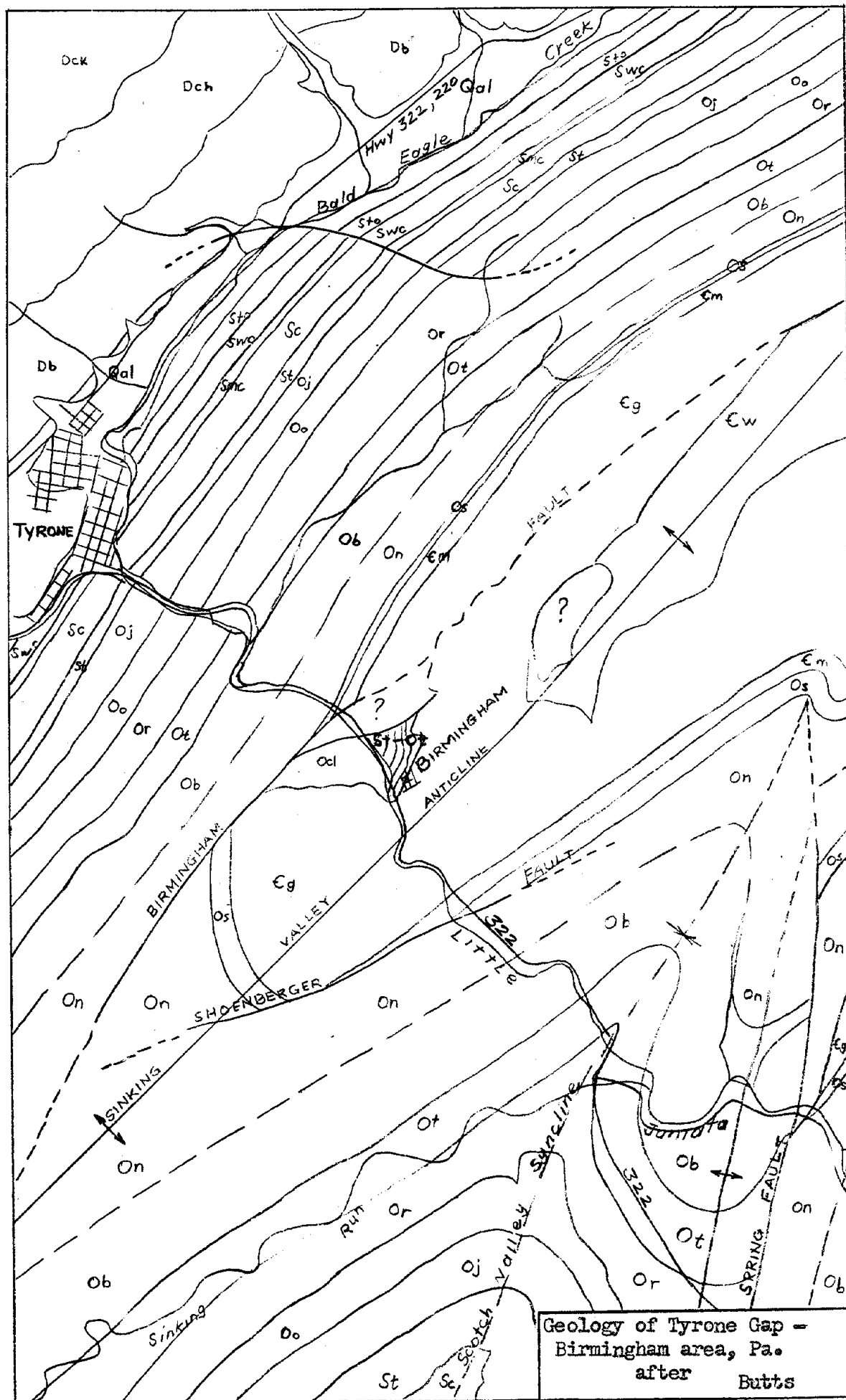
Plummer Hollow red mudstone and sandstone member; named from hollow on southeast side of gap: mudstone, silty, dark red, and sandstone, red, cross-bedded, weak. Lower two-thirds are concealed. Thickness without allowance for faults.      600 feet.

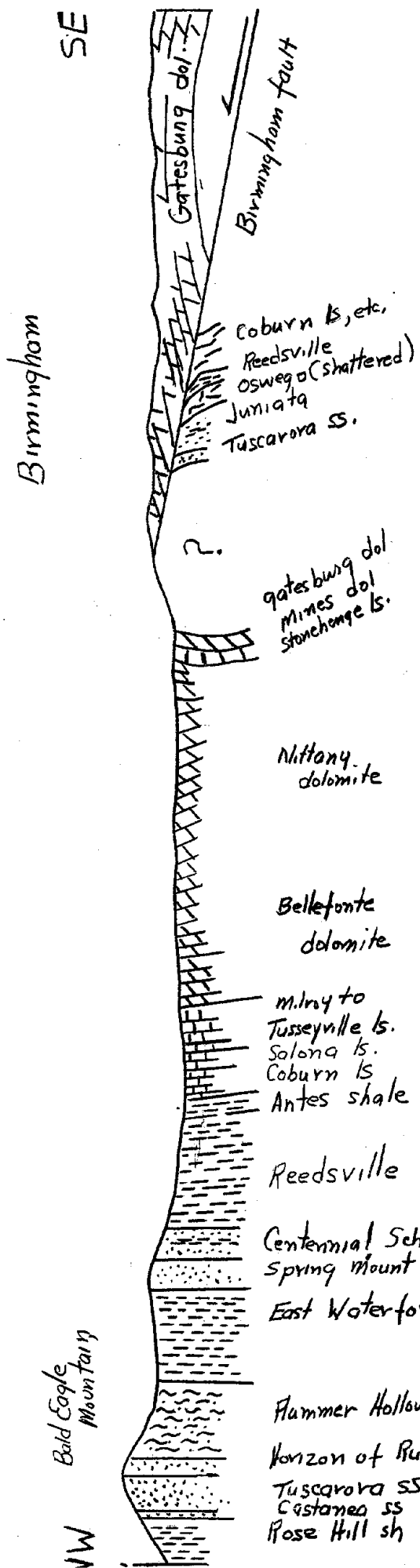
East Waterford red sandstone member: sandstone, thick-bedded, dark red there are some interbeds of greenish gray sandstone and subordinate interbeds of red and some greenish silty shale. Shale chips are common. Cross-lamination is common and generally is of foreset type with original slopes commonly varying from northwest to southwest. Ripple marks can be seen as at 390 feet on traverse from top of member. In many beds, broken surfaces have numerous limonitic specks. These specks are found to be derived from discrete crystals of siderite or ankerite, that commonly enclose some grains of sand. The beds are overturned, dipping  $65^{\circ}$  to  $75^{\circ}$  southeast. The rocks are cut by a number of small faults that commonly dip about  $45^{\circ}$  to the northwest. All appear to be normal faults, increasing the apparent thickness of the beds. There are a few small flexures agreeing with the faults in the nature of the offset. The tectonic interpretation is simplified if it can be supposed that these faults were formed as reverse faults at an early stage of the folding, and were rotated to the present normal fault attitude as folding continued. One fault is well shown at base of exposure opposite side road.      Possible thickness      400 feet.

Sandstone, with dark red and subordinate greenish coarse laminae, Scolithus tubes abundant in a bed near top and at some other levels.      250 feet.

Thickness of Juniata red beds possibly about      1400 feet

(Thickness would be about 500 feet if structure were simple)



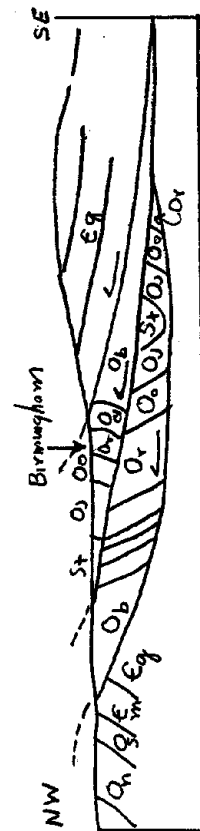


Structure Section from Tyrone Gap to  
Birmingham, Pennsylvania

Scale 1 inch = 1600 feet

Data generally from Butts, 1939

Assembled FM Swartz, 1955



Interpretation by G.W. Stose

SI-10

Oswego or Bald Eagle sandstone (This is the type exposure of the Bald Eagle conglomerate of Grabau, 1909)

Spring Mount sandstone member: sandstone or graywacke, thick-bedded, resistant and forming the subordinate crest of Bald Eagle and Brush Mountains, in middle to upper beds there are a very few quarter-inch quartz pebbles; zones of shale chips, mostly 3 to 4 inches in diameter, are common and provide a very questionable justification for Grabau's use of the term conglomerate. Exposed along railroad tracks on south side of creek. 205 feet

Centennial School sandstone and shale member: sandstone or graywacke with sixteen 1-foot to 6-foot and one 12-foot interbed of shale, mostly green, the highest one red. The red shale suggests that the Oswego inter-tongues toward Bedford County with lower beds of the Juniata formation. 175 feet

Thickness of Oswego sandstone exposed	380 feet
Estimated thickness found in neighboring sections	600 feet

Reedsville shale

Orthorhyncula stvensoni zone: siltstone calcareous, some sandstone and shale, thin-bedded, dark gray, a few 1-inch to 3-inch interlayers of siltstone. 40 feet

Thickness of Reedsville exposed	425 - 465 feet
---------------------------------	----------------

The East Waterford sandstone will be briefly examined, to observe its characteristics, to see the small normal faults, and to provide a basis for comparison with the thinning at Stop No. 3. Time will not be taken to visit the Oswego sandstone along the railroad.

Return to buses on highway southeast of railroad underpass at 27.6 miles

27.8	Turn right, cross creek on Rt. 350.
28.0-28.3	Extensive quarries have been opened in the Middle Ordovician limestones both north and south of the highway.
28.4-29.3	Extensive exposures of Bellefonte and Nittany dolomites.
29.6	<u>STOP No. 3</u> Underthrust block of Birmingham fault. 20 minutes.

Tuscarora sandstone, 200 feet, Juniata red beds, 600 feet, Oswego sandstone, 200 feet, Reedsville shale, 50 feet, and Middle Ordovician limestone, 100 feet, are seen on and near the highway on the northern side of Little Juniata River, in the underthrust block of the Birmingham fault. The fault surface on the south side of the river, overlain by Upper Cambrian Gatesburg dolomite, can be seen from points near the entrance to Greer School at 29.0 miles. Intense shattering of Bald Eagle beds is seen at the entrance to the side road leading to Birmingham at 29.7 miles, and the squeezed out Reedsville and shattered and recemented Middle Ordovician limestones are shown on an abandoned strip of the highway just to the east. The Tuscarora to Reedsville beds are faulted out again before crossing the river. (See map and cross-section prepared from Butts, Tyrone quadrangle report) Presence of Tuscarora to Reedsville beds in the underthrust block is one of the very surprising features of the area, especially since the fault seems to die out in a few miles to the southwest without further evidence of the seemingly major structure required to place these rocks in their observed locations. Alternative hypotheses suggest (1) that the Tuscarora-Reedsville beds occur in a faulted slice of a buried deep syncline of the underthrust block, (2) that they were dropped by a graben structure and subsequently involved in overthrusting. The latter hypothesis demands a more complex tectonic history.

Return to buses near entrance to Greer School. Continue Southeast toward Water Street.

- |           |   |
|-----------|---|
| 30.2-30.8 | Large highway cuts and cliffs of Upper Cambrian Gatesburg dolomite  |
| 31.1-32.0 | Extensive exposures of Nittany and Bellefonte dolomites. Butts found no Axeman limestone between these dolomites when he mapped the area. Cyclic sediments are well developed in the Bellefonte (Coffee Run) dolomites at 31.95 miles. There are large quarries north and above the highway at 31.8 miles.  |
| 32.0      | Railroad underpass  |
| 32.1-32.6 | North of highway are large Pemberton-Union Furnace quarries in Middle Ordovician limestones.  |
| 32.9-36.2 | Fine views of area from altitude of about 1000 feet. One-half mile south of highway is nose of the synclinal loop of Brush and Canoe Mountains. The Oswego sandstones make a prominent shoulder at altitudes of about 1550 feet, with the Tuscarora forming the higher summit at about 2200 feet. Ahead and to the southeast is Tussey Mountain, with Short Mountain knob extending for 2 miles between the gaps of the Little Juniata River and the Frankstown Branch. The Oswego sandstone forms shoulders along Tussey |

Mountain at altitudes of 1400 to 1500 feet, with the Tuscarora crests rising to 1800 feet to 2000 feet. The ganister quarries on Short Mountain produce prominent white cliffs.

- 36.2 Side road to Spruce Creek on left.
- 36.9 Waterstreet intersection. Turn right on Highway No. 22. (If visibility is low or trip far behind schedule, turn left to shorten trip to Huntingdon.) Water Street is located on Water Street fault, downthrown on southeast side.
- 38.5-42.2 Follow Williamsburg Valley to the south with Canoe Mountain to west on right, Tussey Mountain to east on left. There are numerous exposures of Nittany and Bellefonte dolomites.
- 42.4 Yellow Springs intersection; turn left on road to Williamsburg. At the intersection, an anticline exposing Gatesburg dolomite along its axis is cut off on the north by the Yellow Springs fault. Toward Williamsburg, the road crosses folded Gatesburg and overlying and underlying rocks.
- 46.8-46.9 Enter Williamsburg and turn left on road to Huntingdon.
- 47.1 Keep left on road toward Huntingdon.
- 47.2-47.4 Larke dolomite, possibly equivalent to Stonehenge limestone of Bellefonte area.
- 48.2-48.4 Bellefonte dolomite in highway cuts.
- 48.7-48.9 Bellefonte dolomite exposed north of creek.
- 48.9-49.0 Cross bridge over small stream; keep left at intersection.
- 49.4 Keep right on macadam road to Huntingdon.
- 49.7 Ascending Tussey Mountain; Reedsville shale in road cuts.
- 50.0-50.2 Oswego sandstone in road cuts; on right below road at 51.2 is a large quarry where Oswego is worked for ballast.
- 50.2-52.1 Juniata red beds, on southeastern side of synclinal loop in Tussey Mountain.
- 52.1 Entrance on right to road to Loop Fire Tower.
- 52.1 $\frac{1}{2}$  Contact at Mountain summit between Run Gap red sandstone and Tuscarora quartzite. If the weather is good, there are beautiful views to west across the offset ridge of Tussey Mountain to

Canoe Mountain and toward the northwest to Bald Eagle Mountain. Northeast of Short Mountain knob of Tussey Mountain, Round Top is formed on the flank of Tussey Mountain by a doubly pitching anticline.

- 53.5 STOP NO. 4: 10 minutes. Forest lane cut for power line affords a fine view toward northeast of valley region between Tussey and Stone Mountains, carved along main area of Broad Top synclinorium. Low Warrior Ridge is a cuesta formed by Oriskanian Ridgeley sandstone where it dips gently toward the east in the northwestern limb of the synclinorium. To the southeast, it is possible from some places to see the tip of Terrace Mountain at the axis of the synclinorium.

Return to buses. Continue down slope to southeast.

- 53.6-53.7 Castanea sandstone in gutter defines location of top of Tuscarora quartzite.

- 54.8 STOP NO. 5: 20 minutes. Deeply weathered Middle Silurian shales and sandstones, dipping 28 degrees to southeast on the flank of anticline that offsets Tussey Mountain and continues northeastward across neighboring Valley area. The section exposed here is as follows:

#### Wills Creek shale

Calcareous shale and mudrock and impure limestone at 55.1 miles, containing Zygobeyrichia ventricornis. 50 feet

Thickness exposed basal Wills Creek shale 50 feet

#### Bloomsburg red beds

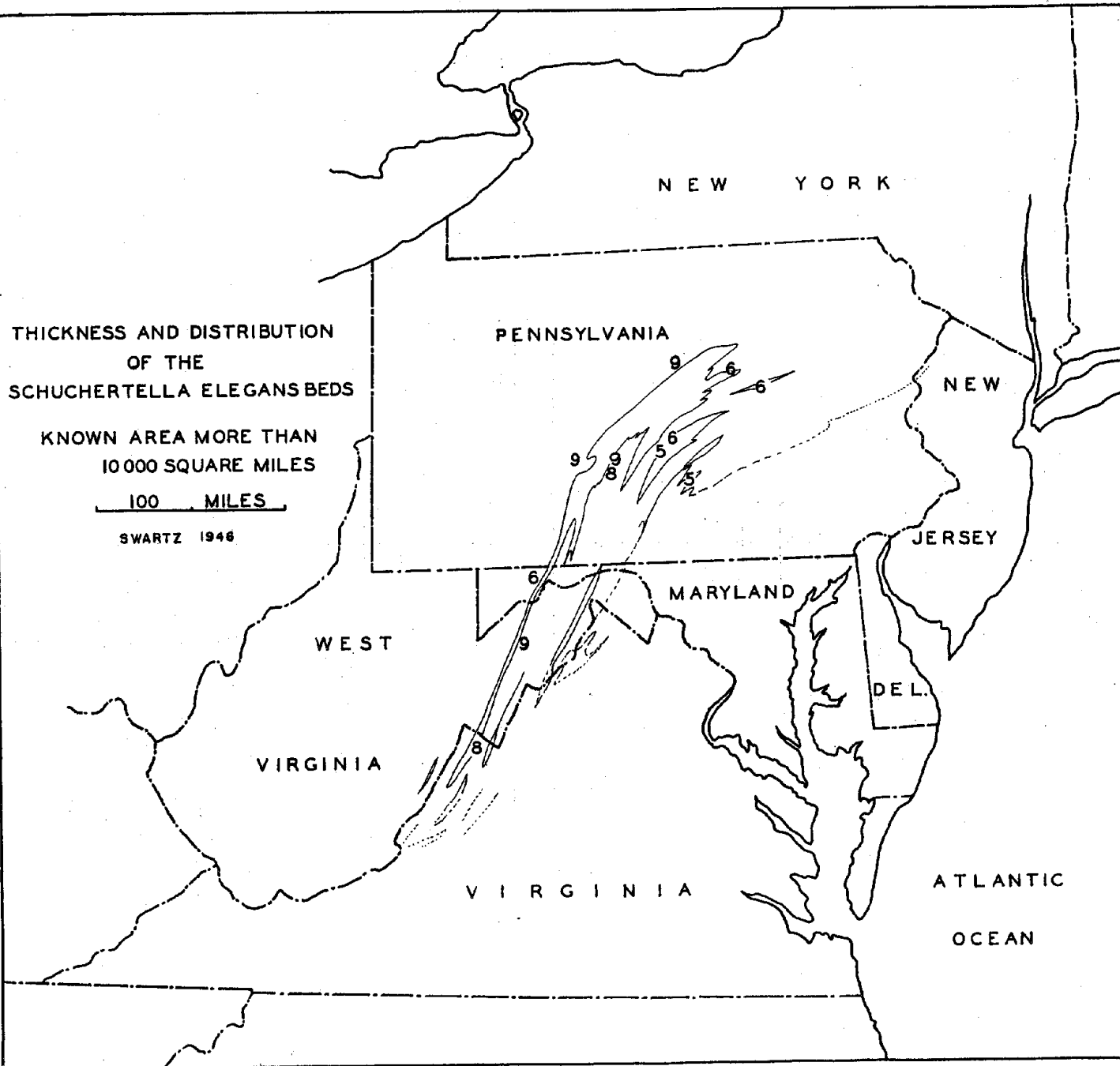
Mudrock, calcareous, breaking to small hackly fragments; at middle is Lucy School siltstone member, 20 feet, with median shaly beds. 50 feet

Thickness Bloomsburg red beds 50 feet

#### McKenzie shale and limestone

Upper shale and limestone member; Kloedenella gibberosa fauna. 70 feet

Rabble Run red bed member; shale and mudrock, red with some greenish interlayers. 50 feet



Lower limestone and shale member; thin-bedded aphanitic limestone with numerous shaly partings, largely concealed. Kloedenella nitida, Velibeyrichia moodeyi, Whitfieldella marylandica and Schuchertella elegans zones occur in this interval. 200 feet

Thickness of McKenzie shale  
and limestone 320 feet

#### Rochester shale

Thin bedded shale, weathered tan-colored, in part with rose-colored tints. Dalmanites limulurus, Drepanellina clarki fauna, with Stropheodonta proutyi, Stegerhynchus neglecta. 30 feet

Thickness Rochester shale exposed 30 feet

#### Keefer sandstone

Sandstone, quartzose above, argillaceous below 20 feet

Thickness of Keefer sandstone 20 feet

#### Rose Hill shale

Shale, olive gray to tan and rose-colored; contains Mastigobolbina typus, Coelospira sulcata fauna. 100 feet

Exposed uppermost Rose  
Hill shale 100 feet

The beds of this section are characterized by sharply defined faunal zones, many of them based on ostracodes, that can be traced widely in the middle Appalachian region; one of the exceptional zones is that of the brachiopod Schuchertella elegans and ostracode Kloedenella cornuta, that has been traced over an area of more than 10,000 square miles although the containing beds are never more than 10 feet thick.

The Rochester and Rose Hill shales are deeply weathered at this location, as compared to the same beds where exposed near the Little Juniata River 6 miles to the north at altitudes of less than 750 feet. It is possible that such weathering may be related to the Harrisburg peneplanation.

Return to buses and continue toward Huntingdon.

- 55.6 Turn left at dead end stop. Continue past road on left at 56.4 miles. There are occasional exposures of Tonoloway limestone in the road cuts, on the rise to Warrior Ridge.
- 58.0 Turn right on Highway 22 to Huntingdon. Continue down dip slope with exposures of Oriskanian Ridgeley sandstone.
- 58.9 Pass last exposures of Ridgeley sandstone.
- 59.2-59.5 Marcellus shale exposed in road cuts. Views of Huntingdon to north across river.
- 59.6-59.7 The Middle Devonian Hamilton shale is extensively exposed in road side cuts, dipping gently toward the east in the western limb of the Broad Top synclinalorium.
- 59.8-60.1
- 60.3 $\frac{1}{2}$ -60.4 $\frac{1}{2}$
- 60.8 STOP NO. 6: 15 minutes. Top of Middle Devonian Hamilton (Mahantango) shale, and base of black shales of Upper Devonian Harrell shale. The Tully limestone has not been recognized in this vicinity.

The rocks are maintaining their gentle southeasterly dip in the northwestern limb of the Broad Top synclinalorium. The Hamilton beds contain members that are sufficiently sandy to make the hills above Huntingdon, but the upper Hamilton and Harrell are weathered out below the escarpment made by the Stone Creek sandstone member at the base of the Brallier shale.

LUNCH: 30 minutes

Return to buses and continue southeast toward Mt. Union.

- 60.8-60.9 Exposures of Harrell shale beyond Cities Service station at 60.8.
- 61.2-61.6 Cross bridge over Juniata River and keep right toward Mt. Union. Brallier shale extensively exposed in highway cuts to 61.8 $\frac{1}{2}$  miles.
- 62.0-62.2 Cuts exposing uppermost Brallier and the basal part of the Chemung shale.
- 62.5-62.8- Side roads on left.
- 63.0
- 63.5 STOP NO. 7: 15 minutes to examine upper part of the Chemung shale and relate the structure and geomorphology of the area.

The upper beds of the Chemung formation are interbedded greenish gray and chocolate colored to reddish sandstones and shales; the reddish beds are symptomatic of intergradation with equivalent parts of the Cat-

skill to the east. Fossils of the Cyrtospirifer disjunctus fauna can be found in some layers.

Structurally, the axis of the Broad Top synclinorium is marked by the point of junction of Terrace Mountain and Sideling Hill, formed where the Mississippian Burgoon sandstone is carried above the level of erosion by the northward rise of the structural axis; at this point, the summit reaches an altitude of 1900 feet, with the mountain nose dropping abruptly in typical synclinal fashion to the river level 1300 feet beneath it at 600 feet. High points on Allegrippis Ridge across the river from the stop are at altitudes of about 1200 feet; between Allegrippis Ridge and Terrace Mountains are divides between entrenched meanders of the Rays-town Branch that suggest development of a former flood plain at levels of a little more than 900 feet. The marked asymmetry of the Broad Top synclinorium is evidenced by the distance of less than 3 miles to Stone and Jacks Mountains on the southeast as compared to more than 10 miles to Tussey Mountain on the west. The summit of Jacks Mountain rises to more than 2300 feet, whereas Stone Mountain in the northwestern limb of the Kishacoquillas Valley anticline is weakened by faulting so that its summits in the area of view are at levels of 1200 to 1500 feet. The high white cliffs at the foot of the mountain are quarry faces in the Oriskanian Ridgeley sandstone.

Return to buses and proceed toward Mt. Union.

- 63.8-65.8      Cross outcrop belt of Catskill red beds, with change to northwest dip, beyond axis of the synclinorium at 65.0 miles. From 63.8 to 64.5 miles the Catskill is fairly well exposed along and on slopes above an abandoned section of the highway; farther on, exposures are poor but red soils are prominent about to a side road at 65.8. The rapid steepening of dips southeast of the synclinal axis is shown in the ledges in the cliffs south of the river.
- 66.1-66.2      Upper Chemung in cut on north side of highway in outskirts of Mill Creek dips 55 degrees northwest, with pronounced creep to west at summit of cut.
- 66.5 $\frac{1}{2}$ -66.6 $\frac{1}{2}$       Beyond intersection in Mill Creek at 66.5 miles, highly fossiliferous Chemung shale is exposed in cuts on left at 66.6 to 66.7 miles; the beds are subvertical with pronounced creep to west at summit of cut.
- 66.7-67.2      Extensive exposures of the Devonian shales continue in cuts on north side of highway from 66.7 to 67.2 miles, with the strata generally overturned and dipping to southeast at angles of around 70 degrees. The Stone Creek sandstones of the Brallier are present but not prominent at 66.9 miles; the Burket black shale is well shown at 67.0 miles; Hamiltonian

Mahantango shales are exposed at 67.1 to 67.2 miles.

- 68.0 Entrance on right to Mapleton plant of the Philadelphia Glass Sand Company.
- 68.2 $\frac{1}{2}$ -68.4 High cliffs of Ridgeley sandstone. The rock is coarse-grained, with poorly defined, thick bedding. The highway cuts the rock obliquely to the strike. The Ridgeley is a valuable source of glass sand in this area; it is of interest that both at Mapleton and at Berkeley Springs, West Virginia, the best deposits are in areas where the dips are at high angles, rather than in areas of low dips as in Warrior Ridge.
- 68.6 Basal Keyser and upper Tonoloway in road cut on right. Silicified stromatoporoides are abundant in the Keyser beds.
- 69.7 Entering axial region of Kishacoquillas Valley or Jacks Mountain anticline. Tuscarora sandstone on left at 69.7.
- 70.2 STOP NO. 8: 20 minutes. Jacks Narrows: structure of Jacks Mountain anticline of Kishacoquillas Valley anticlinorium.

The exceptional anticlinal exposures in Jacks Narrows where the Juniata River cuts through Jacks Mountain, have been known since the time of the early reconnaissances made a century ago by H.D. Rogers. Topmost Reedsville shale is exposed along the highway at the axis of the fold; neighboring inner crests of the mountain are made by the Lost Run conglomerate and Oswego sandstone; the high ridge of Jacks Mountain is made by Tuscarora sandstone, and is scarred by ganister workings.

The following section can be seen in the Narrows.

#### Tuscarora quartzite

Quartzite or quartzitic sandstone, partially exposed near ends of the Narrows; thickness uncertain but possibly about 500 feet

#### Juniata red beds

Largely concealed under talus from Tuscarora quartzite; extensively faulted beds of the East Waterford member are exposed in southeastern limb of anticline with thickness of about 500 feet. Measurement from Lost Run to Tuscarora beds in northwestern limb of anticline gives a thickness of 900 feet, but this is most likely reduced by faulting. Judging from other sections in general region the thickness should be between 1200 and 1500 feet.

## Lost Run conglomerate

Conglomeratic sandstone and conglomerate, thick-bedded and resistant and forming main ledges of inner ridges; these and next lower strata are best seen on ganister company's trackway about 100 feet above highway, where pebbles are numerous, commonly measure  $\frac{1}{2}$  inch to 1 inch in diameter, and consist of vein quartz, quartz veined quartzites and other varieties.

200 feet

## Oswego sandstone

Sandstone, greenish gray, with some interlayers of shale.

121 feet

## Reedsville shale

Orthoryncula stevensoni zone: sandstone, medium-grained, gray to greenish, medium-bedded to thick-bedded, with some interlayers of greenish shale; O. stevensoni profuse 80 to 95 feet above base. In coarseness of sand and small proportion of shale, these strata are suggestive of the Oswego sandstone; but they correspond to sandstones of this zone included in Reedsville by original definition at Reedsville.

120 feet

Shale, greenish gray, thin-bedded, with numerous  $\frac{1}{4}$  inch to 10 inch interlayers of comparatively quartzose siltstone or very fine-grained calcareous sandstone, and some thin beds of fossiliferous limestone. Thickness on trackway 50 feet, below trackway about 100 feet, total 150 feet

Thickness of exposed Reedsville  
formation

270 feet

The Reedsville shale at road level at the axis of the anticline is gently flexed, forming small anticlinal and synclinal folds in which the axial planes tend to have a fan-like disposition. The major fold is markedly asymmetrical, with vertical dips in the northwestern limb; the dips in the Tuscarora sandstone of the southern limb are gentle, not steepening to more than 20 degrees. Some steeper dips occur locally in the Oswego-Lost Run-East Waterford beds where exposed along the highway east of the axis, where there is much disturbance due to faulting. The fault surfaces generally are coated with chlorite.

An especially interesting feature is the flattening of dip at the summit of the Lost Run ledges of the northwestern limb of the fold. The ledges rise almost vertically for 300 feet or more and then reduce dip markedly in approach to the axis of the fold.

Return to buses and continue toward Mt. Union.

- 70.2-71.0 Exposures of uppermost Reedsville, Oswego, Lost Run and East Waterford beds, showing extensive faulting.
- 71.0-72.0 Mountain slopes covered with talus. Summit of Jacks Mountain south of river forms a long dip slope.
- 72.0-72.1 Uppermost Tuscarora quartzite overlain in roadside knolls by Castanea sandstone.
- 72.1 $\frac{1}{2}$ -72.6 Extensive exposures of Rose Hill shale. Note river-worn boulders at tops of road cuts.
- 72.7-72.8 McKenzie shale and limestone.
- 72.8 Highway on right crosses bridge to Mt. Union.
- 72.9 STOP NO. 9: 20 minutes. Upper Silurian section at Mt. Union.

The Mt. Union section (Swartz, 1934) provides the most complete and continuous exposures of Silurian sediments that can be found in central Pennsylvania. Because of limited time, only the upper McKenzie, Bloomsburg, Wills Creek and lower and Middle Tonoloway beds will be examined. The section as a whole, however, can be summarized as follows.

#### Lower Devonian series

##### Helderberg group

New Scotland limestone, gray, cherty, containing Eospirifer macropleurus fauna; seen with beds through upper Tonoloway near river east of bend where Highway 22 turns northward toward Lewistown. 30 feet

Coeymans limestone, crystalline, crinoidal, containing Gypidula coeymanensis fauna. 10 feet

#### Silurian System

##### Cayugan series

##### Keyser limestone

Paintersville limestone member, thinly laminated. 30 feet

Hollidaysburg limestone member, not laminated or lumpy. 25 feet

Mt. Rock limestone member, thick-bedded, lumpy; Gypidula prognostica fauna; Merista typa 63 to 58 feet. 100 feet

Thickness Keyser limestone 155 feet

### Tonoloway limestone

Upper limestone member, largely laminated; some oolitic chert 30 to 40 feet below top. 120 feet

Dolomitic limestone member, laminated, tending to weather earthy; basal 85 feet concealed across gully. 385 feet

Middle limestone member; contains obscure cycles beginning with oolitic fossiliferous limestones with sharp base, continuing above into banded limestone, fossiliferous in some instances, grading into dolomitic limestones that dominantly are laminated, but contain some  $\frac{1}{2}$ -foot to 1-foot interlayers of non-banded vugular dolomites. Hindella congregata, Zygobeyrichia dorsocristata. 145 feet

Argillaceous limestone member, laminated, grading into calcareous shale. 120 feet

Basal limestone member, forming lowest prominent limestone above Bloomsburg. 10 feet

Thickness Tonoloway limestone 780 feet

### Wills Creek shale

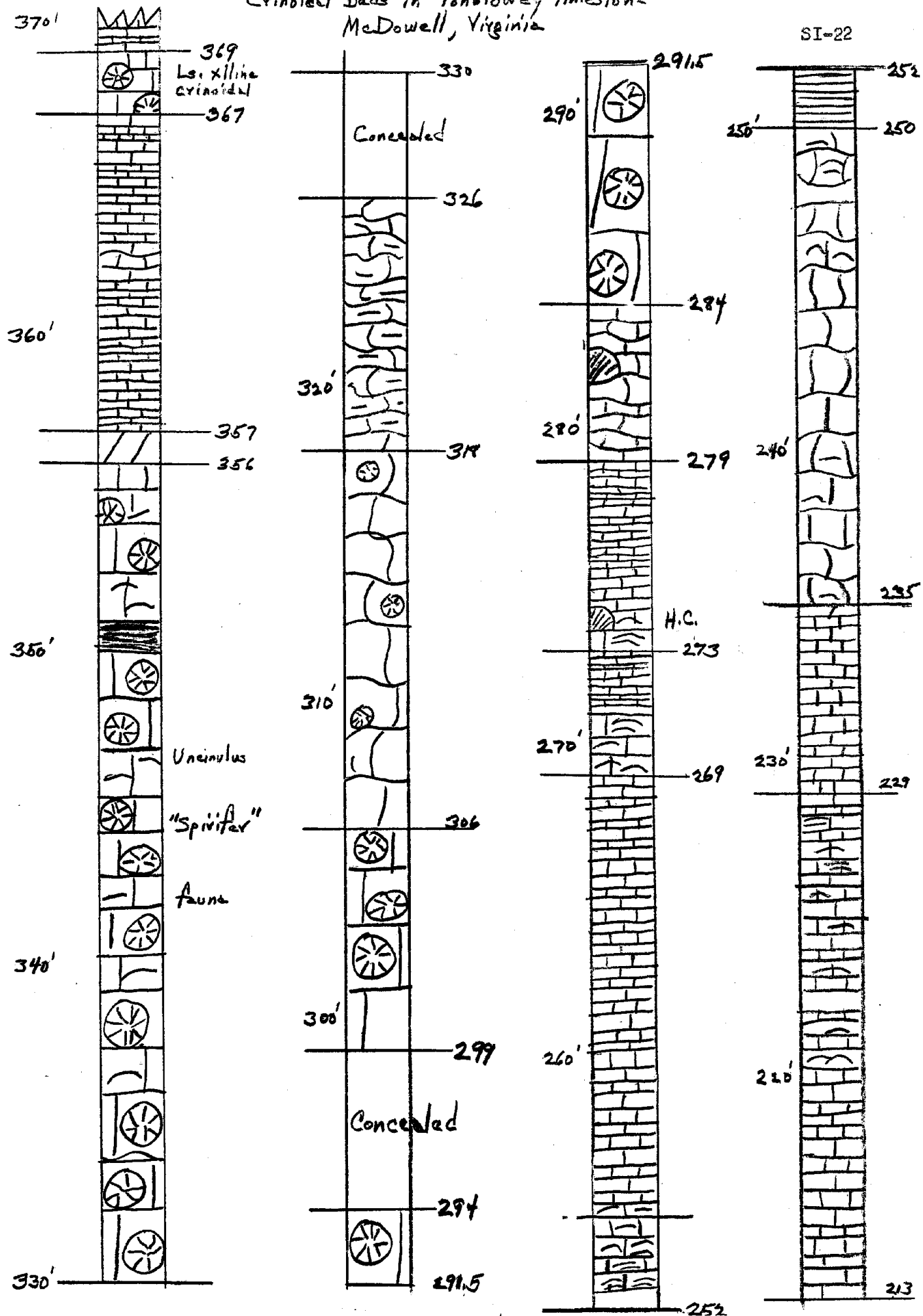
Composed dominantly of cyclic successions of dolomitic limestone, weathering grayish brownish yellow and in part earthy, overlain by thin-bedded calcareous shale that grades upward into mudrock weathering grayish yellowish green; at some horizons the mudrock is grayish red or red-splotched; these are tongues giving evidence of eastward gradation into Bloomsburg red beds. 460 feet

### Bloomsburg red beds

Upper mudrock member, calcareous, breaking into small hackly fragments; some greenish layers and splotches, and with greenish interbeds near top. 40 feet

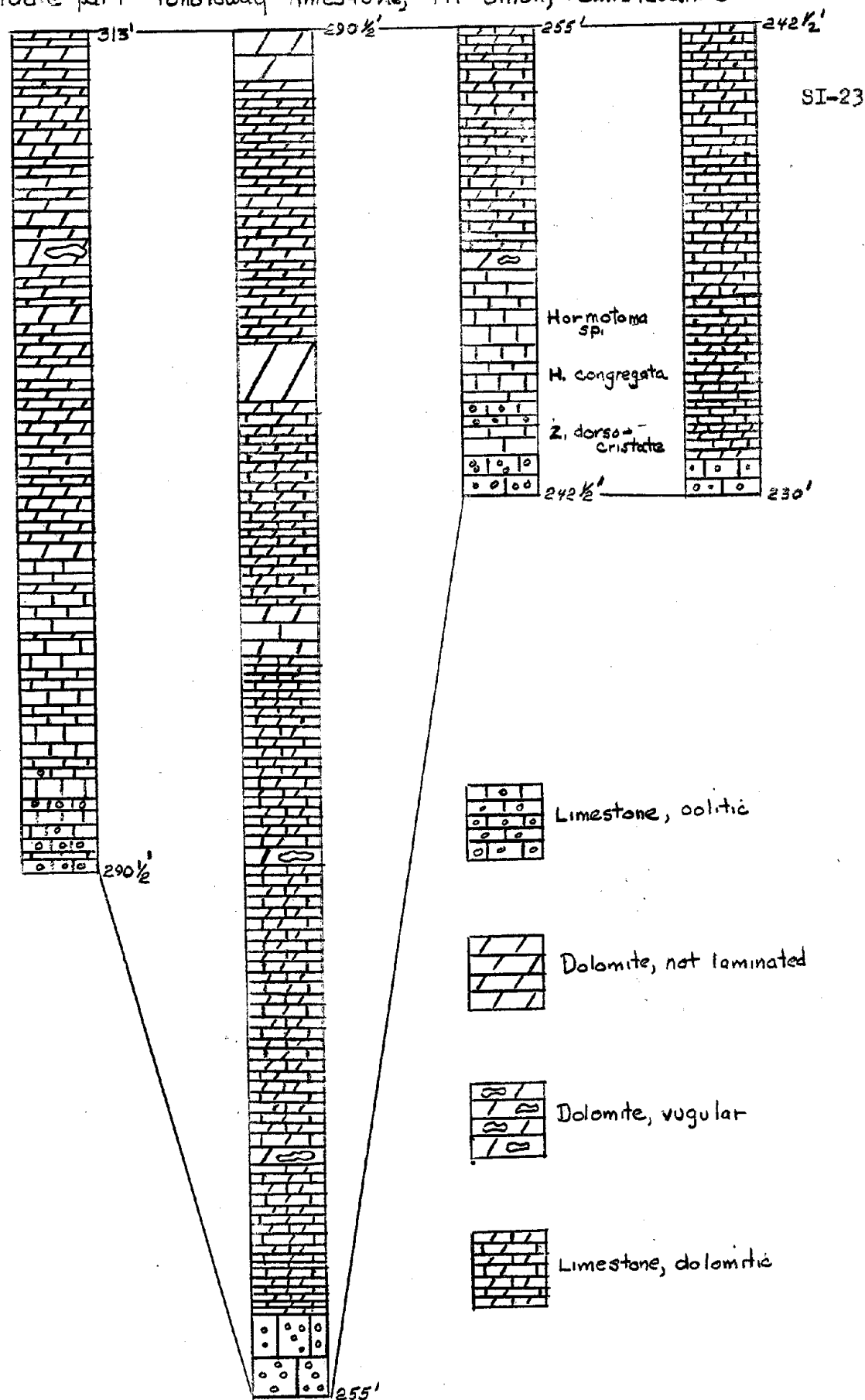
Lucey Furnace siltstone member, with 7 feet of green shale and red mudrock at middle; 1-inch calcareous nodules abundant 3 to 7 feet below top. 30 feet

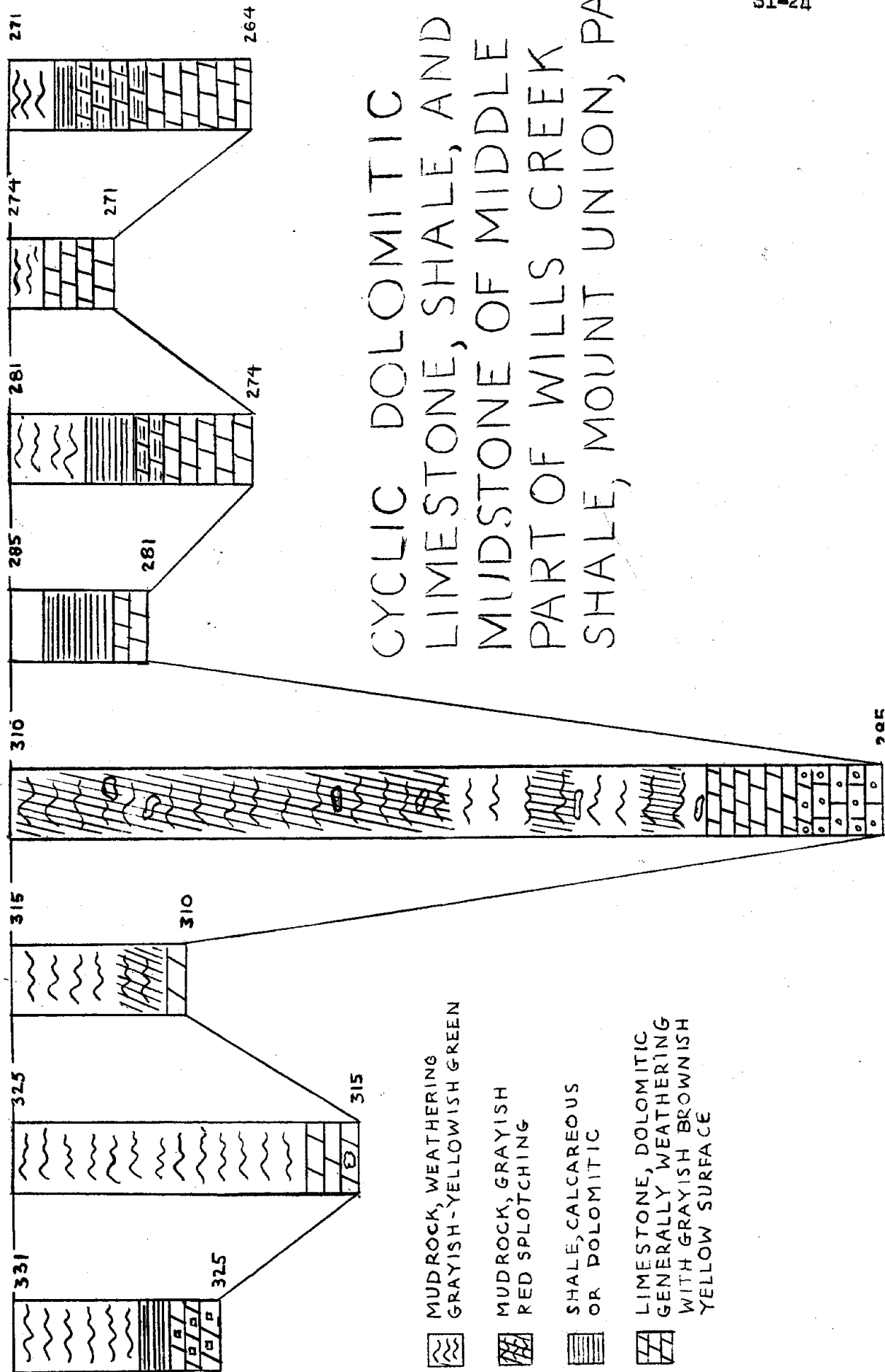
Crinoidal beds in Tonaloway limestone  
McDowell, Virginia



Cyclic oolitic fossiliferous limestones and, largely laminated limestones and dolomites,

Middle part Tonoloway limestone, MT Union, Pennsylvania





CYCLIC DOLOMITIC  
LIMESTONE, SHALE, AND  
MUDSTONE OF MIDDLE  
PART OF WILLS CREEK  
SHALE, MOUNT UNION, PA.

Lower mudrock member; near top are numerous small silty sedimentary dikes, some of them 3 or 4 feet in length, their upper limits about 2 to 3 feet below top of member.

38 feet

Thickness Bloomsburg

108 feet

# Niagaran series

## McKenzie shale and limestone

Upper shale and limestone member, the limestone interlayers containing Homospira marylandica, Stegerhynchus andrewsi, ostracodes of Kloedenella gibberosa zone.

70 feet

Rabble Run red bed member

70 feet

Lower limestone and shale member, thin-bedded aphanitic limestones with thin partings of gray calcareous shale; several small bodies of flat-pebble limestone conglomerate. Faunas of Kloedenella nitida, Velibeyrichia moodeyi, Whitfieldella marylandica, Schuchertella elegans zones

220 feet

Thickness McKenzie shale and limestone

360 feet

# Clinton group

Rochester shale, Drepanellina clarki fauna

40 feet

Keefer sandstone; calcareous, quartzose sandstone with crinoid plates, some oolitic hematite in uppermost 6 inches, 34 feet, above, underlain by argillaceous and arenaceous limestone and some shale and minor hematitic limestone containing Schuchertella subplana fauna, below,

47 feet

Rose Hill shale, colored olive green and in part pale grayish red; there are a few thin interlayers of impure limestone and rare 1-inch or 2-inch interlayers of quartzose siltstone; 1 foot below top is a 3-inch layer of oolitic hematite. Contains zones of Mastigobolbina typus, and other characteristic ostracodes.

725 feet

Castanea sandstone, greenish gray fine-grained sandstones and silt stones and some shale, dark red 12 to 20, 32 to 33½ and 40 to 47 feet above base. Scolithus tubes common.

58 feet

Thickness Clinton group

870 feet

## Alexandrian or Medinan series

Tuscarora quartzite, upper 210 feet partly exposed; thickness  
about 500 feet

The cyclic sediments of the Wills Creek and Middle Tonoloway give a suggestion of more or less rhythmic subsidence and clearing of the water, followed by sedimentary upbuilding with reinflux of clay in the Wills Creek, modification of water chemistry favorable for dolomite deposition in the Tonoloway. During Tonoloway deposition subsidence improved interchange with sea waters, and faunas with marine affinities were able to subsist for short periods. Salinity gradients lowered northward are suggested by absence at Mt. Union of more abundant marine faunas found to south, as at McDowell, Virginia, where there are thick crinoidal interbeds in the middle Tonoloway.

In the Bloomsburg, the Lucey School siltstone member is a westward tongue from the coarser and thicker Bloomsburg sandstone member of sections along Blue Mountain, which in turn appears to intergrade in northwestern New Jersey with much or all of the red Greenpond conglomerate. Persistence of the triplicate sequence of the Lucey Furnace member over some hundreds and perhaps a thousand or more square miles, indicates deposition in a body of water favoring extensive distribution of sediments, rather than directly by rivers where lateral variation should be much more rapid.

Return to buses at 73.2 miles, and continue toward Lewistown

The route from Mt. Union to Lewistown follows a synclinal valley of folded Silurian and Devonian shales, limestones and sandstone. The Juniata River flows through the more southeasterly part of the same valley, except where it is close to the route near McVeytown. The flanking ridges are formed by Tuscarora quartzite where brought up by neighboring anticlines; Jacks Mountain is on the left or northwest, Blue Mountain on the southwest.

- 73.2-78.3 Follow strike of Tonoloway Wills Creek beds, with occasional exposures of limestone and some shale. There are fine views of Jacks Mountain on left, and of a low hogback made by Ridgeley sandstone on right. Road to Newton Hamilton on right at 73.8 miles.
- 78.3-79.0 Highway curves to right cutting through the hogback of the Ridgeley sandstone.
- 79.0-82.0 Highway follows a synclinal valley in Middle Devonian shales. There are some views of Blue Mountain on right.

- 82.0-82.6 Northeastward rise of parts of secondary folds of valley brings Upper Silurian Keyser and Tonoloway limestones to surface at roadside; Ridgeley sandstone continues to form ridge along northwest side of highway throughout remainder of route to Lewistown.
- 83.9 Enter McVeytown, with main road intersection at 84.3 miles.
- 86.2 One of sand plants of Philadelphia Glass Sand Co. located along railroad to right across Juniata River, is supplied from quarries in Ridgeley ridge to left of highway at 87.2 miles. This sand does not appear to be of glass sand grade.
- 89.5 Strodes Mills; road to Lockport on right; there are fairly good Tonoloway exposures at this locality.
- 90.6-91.0 Roadside exposures of Keyser and Tonoloway limestones. There are fine views of Blue Mountain on right.
- 94.3 City limits of Lewistown. Viscoseplant on right opposite 95.5 miles.
- 95.6 Take right fork onto Third Street, leaving Route 22.
- 96.3 Turn left on Valley Street at dead end of Third Street.
- 96.7 Turn right on Walnut Street at second traffic light. Go one block and turn left on Logan Street at 96.8 miles.
- 96.9 Sandstone beds in Hamilton shale.
- 97.0 STOP NO. 10: 15 minutes. Mt. Rock section; Hamilton shale ~~to top of~~ Tonoloway limestone. This stop will be omitted if trip is running late.

The exposed section is as follows.

#### Devonian System

#### Middle Devonian series

Hamilton shale; thin-bedded shales, with several interbeds of fine-grained to medium-grained graywacke sandstone that are 10 feet and more in thickness. The shales are largely concealed. Thickness to highest exposed beds 400 feet

Marcellus black shale; where partially exposed in prospect quarry south of road is comparatively blocky rather than fissile. Total thickness probably more than 200 feet.

Onondaga shale and limestone; concealed; a few loose pieces of weathered argillaceous limestone and calcareous shale were formerly available. 125 feet

### Lower Devonian series

#### Oriskany group

Ridgeley sandstone; medium- to coarse-grained quartzos sandstone, moderately well cemented by silica overgrowths. Profuse fossils of the Costispirifer arenosus, Rensselaeria ovoides fauna are represented by well preserved molds in many layers. 25 feet

Concealed; interval may include beds of both the Ridgeley and Shriver formations. 40 feet

Shriver siliceous limestone; calcareous, siliceous, perhaps sparingly argillaceous rock; uppermost beds contain fine silt; carbonate seems rarely to form as much as 50 per cent of rock. Some of more cherty parts of rock contain abundant sponge spicules; callophane is present in small amounts. A trilobite related to Synphoroides biardi of Gaspé occurs near top; ostracodes and a fair number of brachiopods occur in upper and middle parts 114 feet

#### Helderberg group

Mandata shale, partly concealed. 44 feet

New Scotland limestone, aphanitic, cherty; Eospirifer macropleurus fauna. 10 feet

Coeymans limestone, mostly crystalline, crinoidal, contains abundant Gypidula coeymanensis. 6 feet

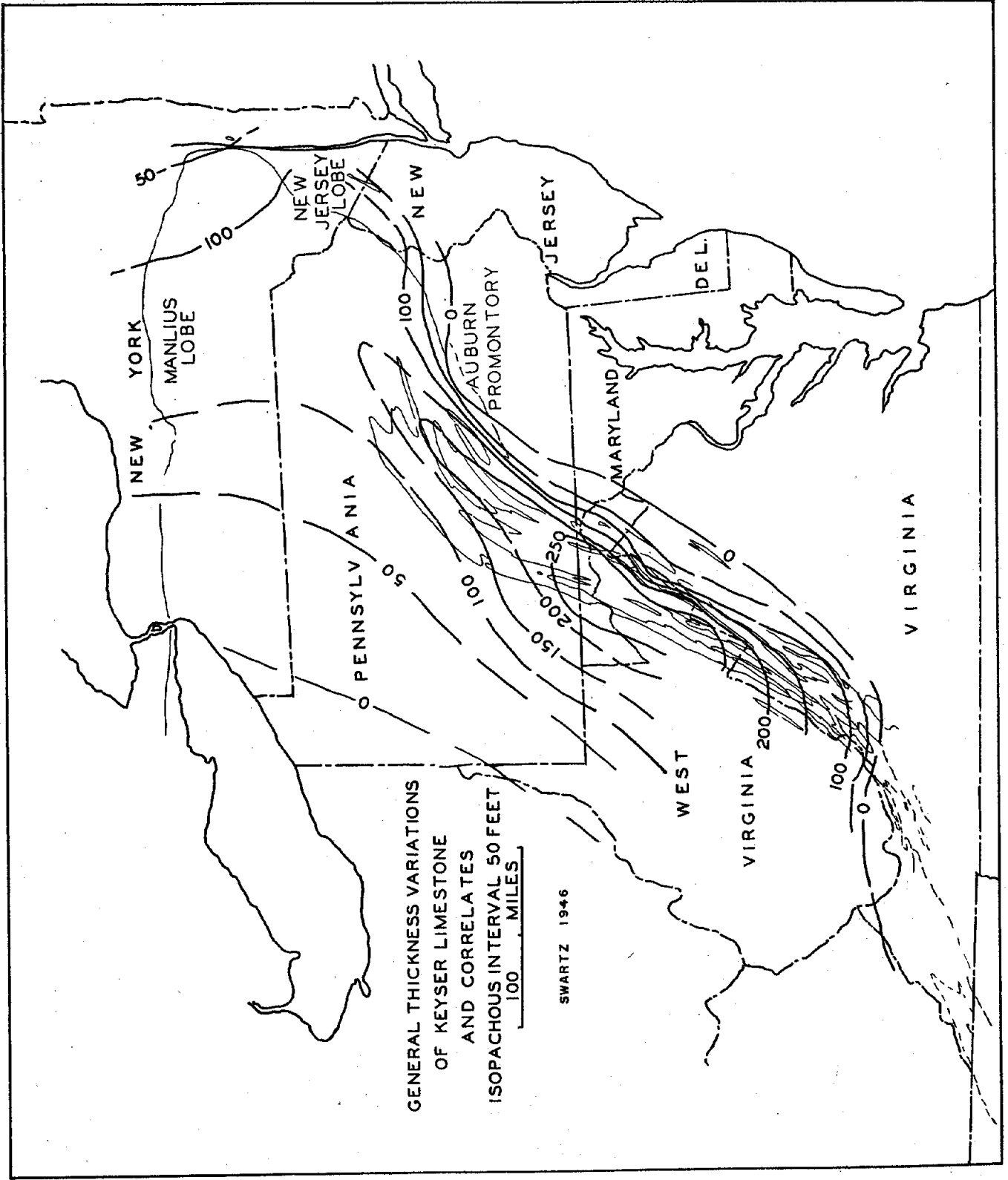
### Silurian System

#### Cayuga series

#### Keyser limestone

Paintersville limestone member, laminated aphanitic limestone 35 feet

Hollidaysburg limestone member, fine to medium crystalline and some aphanitic limestones, argillaceous in part; fossils include Rensselaerina mutabilis, Uncinulus keyserensis, Howellella vanuxemi var., and near base Merista typa. 75 feet



Mt. Rock limestone member; lumpy, argillaceous limestone; crystalline, crinoidal limestone 48 to 60 feet above base; basal 42 feet generally not lumpy, but do not have laminated character of Tonoloway limestone. Chonetes jerseyensis fauna, with Stenocisma deckerensis, Gypidula prognostica, Atrypa reticularis, Merista typa in upper half, Leperditia scalaris, Zygobeyrichia barretti in lower 40 feet. 85 feet

Thickness of Keyser limestone 195 feet

Tonoloway limestone, laminated, aphanitic; thickness of uppermost beds exposed behind buildings on south side of road. 25 feet

The Keyser and Helderberg limestones and faunas were described in detail by J.B. Reeside, Jr., in 1917.

Return to buses. Continue to northwest returning to Route 322; do not cross creek at bridge at 97.2 miles.

97.5 Turn right on Route 322.

99.0 Cross intersection in Burnham, and proceed northwestward through Yeagertown on Highway 322. The intersection in Burnham is located on the axis of one of several secondary synclines that wrinkle the Silurian and Lower Devonian sediments between Mt. Rock and Jacks Mountain. In Kishacoquillas Gap, ahead, note level summit of ridge formed by Lost Run conglomerate at an altitude of 1150 feet, as compared to altitudes of 1800 to 1900 feet for the main mountain crests held up by Tuscarora quartzite.

101.0-101.1 Cross bridge over Kishacoquillas Creek in southeastern part of Kishacoquillas Gap. A road to right at north end of bridge leads toward the Tuscarora-Clinton portion of the Kishacoquillas Gap exposures.

101.3 Highest exposed East Waterford beds in gully northeast of road.

101.5 STOP NO. 11: 20 minutes. Exposures of reddish Lost Run conglomerate, believed to represent principally the eastward extension of Spring Mount member of Oswego sandstone at Stop 1A; Oswego sandstone representing primarily the coarsened extension of the Centennial School member of Oswego at Stop 1A; graywacke sandstone of the Orthorhyncula stvensoni zone, and numerous siltstone interlayers of upper Reedsville beds, markedly increased in number and thickness as compared to upper Reedsville of Stop 1A.

The section at Kishacoquillas Gap, including Silurian rocks at east end of gap that will not be visited, can be summarized as follows.

### Silurian system

#### Niagran series

#### Clinton group

Rochester shale, thin-bedded, with some thin interlayers of medium crystalline limestone; Drepanellina clarkei fauna. 35 feet

Keefer sandstone; medium-bedded, resistant sandstone, with molds of a few crinoid fragments, 20 feet; above, makes prominent ledge on bank of creek, and is underlain by 35 feet of arenaceous shale and limestone. 55 feet  
Total thickness

Rose Hill shale, olive green and purplish, a few 1-inch or 2-inch layers of siltstone; fossils of Mastigobolbina modesta, M. lata, Zygobolba bimuralis and Z. decora zones have been collected at this locality. 710 feet

Castanea sandstone, greenish to whitish, red 10 to 19 feet and 62 to 66 feet above base. 72 feet

Thickness of Clinton Group 872 feet

#### Alexandrian or Medinan series

Tuscarora quartzite, thick-bedded, resistant; concealed beds 110 to 300 feet below top probably include a small proportion of shaly interlayers. 400 feet

### Ordovician System

#### Cincinnatian series

#### Juniata red beds

Run Gap quartzitic sandstone member, thick-bedded, resistant; upper 115 feet brownish red; next lower 145 feet are gray, the whole somewhat lighter colored than in other sections of area. 260 feet

Plummer Hollow red mudstone member; concealed, except for 55 feet at top that are transitional with Run Gap member. Thickness provisionally assigned to member, on basis of better section on Long Mountain. 500 feet

East Waterford red sandstone member, extensively cross-laminated; lower 330 feet, with extensive limonitic speckling, are exposed on hillside away from highway; total thickness if the overlying concealed interval is not thickened by faulting is about 1000 feet; using other sections in area a more probable thickness would be 800 feet

Thickness of Juniata, including  
Run Gap beds that also show marked  
relation to Tuscarora formation: 1560 feet

Lost Run conglomerate; pebbles occurring in numerous zones commonly reach maximum diameters of 1 to 2 inches, more rarely 3 or 4 inches; they consist dominantly of chlorite splotched milky quartz, quartz-veined metaquartzites from a chlorite zone of metamorphism as interpreted by Watston (personal communication), red jasper, rare gray or white chert. Peculiar 2-inch concretionary structures occur at a number of horizons. Matrix dominantly is reddish, but is gray in lowest 20 feet. 345 feet

Oswego sandstone, medium- to coarse-grained above; fine-grained with some shaly interlayers below; limonitic speckling is common. 255 feet

#### Reedsville shale (type)

Orthorhynacula zone: graywacke sandstone like Oswego sandstone but fossiliferous. O. stevensoni; gastropods and pelecypods more common near top; base poorly exposed. 48 feet

Concealed. 42 feet

Shale, dark gray to greenish, with numerous interlayers of blocky fine-grained sandstone or siltstone, decreasing in abundance below; the interlayers commonly  $\frac{1}{2}$  to 1 foot, more rarely 2 to 5 feet thick; there are also interlayers of limestone, containing crinoid fragments, bryozoa and other fossils; some of the limestones occur as clastic concentrations grading above into the fine sandstone or siltstone and then into shale. 200 feet

Shale, less well exposed (not measured)

Upper Reedsville beds  
described 290 feet

The eastward coarsening of the Lost Run, Oswego and upper Reedsville is in each instance symptomatic of derivation of detritals from the easterly old land of Appalachia. The pebbles of the Lost Run are of special interest in the sense that they show the fabric as well as mineralogical composition of rocks of the source region.

Kishacoquillas Gap lies within the area of maximum thickness of the post-Martinsburg Ordovician rocks of the region, as is illustrated in the isopachous map for the Bald Eagle (Oswego)-Juniata sediments. Total thickness is more than 2000 feet; in the 45 miles airline distance to Susquehanna Gap north of Harrisburg the thickness drops to 165 feet; this remaining wedge then disappears within a few miles. The developing unconformity also cuts into the Reedsville-Martinsburg, so that even at Harrisburg the reduction of thickness between the Tuscarora and highest preserved Martinsburg is at least a half-mile as compared to Kishacoquillas Gap. The sedimentary record at Kishacoquillas Gap is in some ways a better guide to the easterly events than are the structures of eastern Pennsylvania. The development and upward coarsening of the Reedsville reflects the increasing altitude of the easterly source lands and westward shift of the margin of sedimentation. The continued coarsening of sediments into the Lost Run conglomerate witnesses the rise of the source lands to maximum elevation. Subsequent erosion and lowering is reflected by the progressively finer detritus of the East Waterford and Plummer Hollow beds. The Run Gap sandstone represents renewal of easterly tectonic activity, and these rocks form the beginning of sedimentation of the Tuscarora-Clinton deposits which are united as a sedimentary complex by their common interfingering with the Shawangunk conglomerate.

Within the basin of deposition, the margin of waters favorable to marine life shifted to the west, so that after deposition of the Orthorhynacula beds marine fossils are not found again until the Clinton sediments are reached.

Return to buses and continue toward State College, on Route 322.

- 102.0 Railroad crossing. Enter Reedsville. Traffic light at 102.2 miles.
- 102.3½ Top Coburn limestone in drive on north side of highway.
- 102.4 Intersection, with road to Belleville on left. High cuts, chiefly in Salona limestone.
- 102.6 Tusseyville limestone, with Maclurites logani fauna, ostracodes.
- 103.0 Cross Tea Creek; Middle Ordovician limestones and Tea Creek dolomite are duplicated by minor faulting in this area.
- 103.2 Road to left provides part of type exposures of Tea Creek and Coffee Run dolomites of Bellefonte group.
- 103.5-107.5 Rise to level of Valley Floor or Harrisburg peneplain, here with levels of 800 to 900 feet, and cross remainder of Kishacoquillas Valley mostly at these levels except in Valley near Milroy. There are fine views of Jacks Mountain flanking

valley to southeast, Front Mountain to northwest. Pitching synclinal and anticlinal folds offset Stone Mountain on west. Toward northeast, there are fine views of synclinal Strong Mountain and Thick Mountain. The high crests of all these mountains are formed by Tuscarora sandstone and rise to levels of 1800 to as much as 2200 feet; shoulders and subordinate ridges on the valley side of the Tuscarora-made crests mark the position of the Lost Run conglomerate, and commonly have altitudes of 1400 to 1600 feet or, along Strong and Thick Mountains, 1600 to 1700 feet.

- 105.3-106.0-  
106.3 Pass three roads leading to Milroy.
- 107.6 Enter Gap in first ridge of the Seven Mountains area. There are high, subvertical ledges of Lost Run conglomerate.
- 107.7-108.5 East Waterford and Plummer Hollow beds, concealed below talus.
- 108.6 Characteristic Run Gap red quartzitic sandstone, in subvertical ledges.
- 108.7 Tuscarora talus, in strike of main ridge of Front Mountain. Castanea sandstone forms exposed ledges a hundred feet and more above highway.
- 108.9-109.0 Basal Rose Hill and Castanea, crumpled and faulted in axis of syncline between Front and Long Mountains.
- 109.0-110.9 Rise on dip slope of Long Mountain. Highway curves in a horse shoe at 109.3-109.5. Spring at 110.0
- 110.1 $\frac{1}{2}$ -110.3 Castanea sandstone, green and red, cut by numerous Scolithus tubes; bedding surfaces clotted by worm castings.
- 110.4 $\frac{1}{2}$ -110.6 Tuscarora quartzite; shaly interlayers abundant above middle; ripple mark extensively developed in beds near base, that are laminated parallel to general bedding, as compared to higher, cross-laminated layers.
- 110.6-110.7 Run Gap red quartzitic sandstone.
- 110.8-110.9 Plummer Hollow red mudstone beds, with sandstone interlayers. This is one of best exposures in region.
- 111.4 Enter Centre County at summit of grade.
- 111.9 Plummer Hollow beds near axis of syncline.

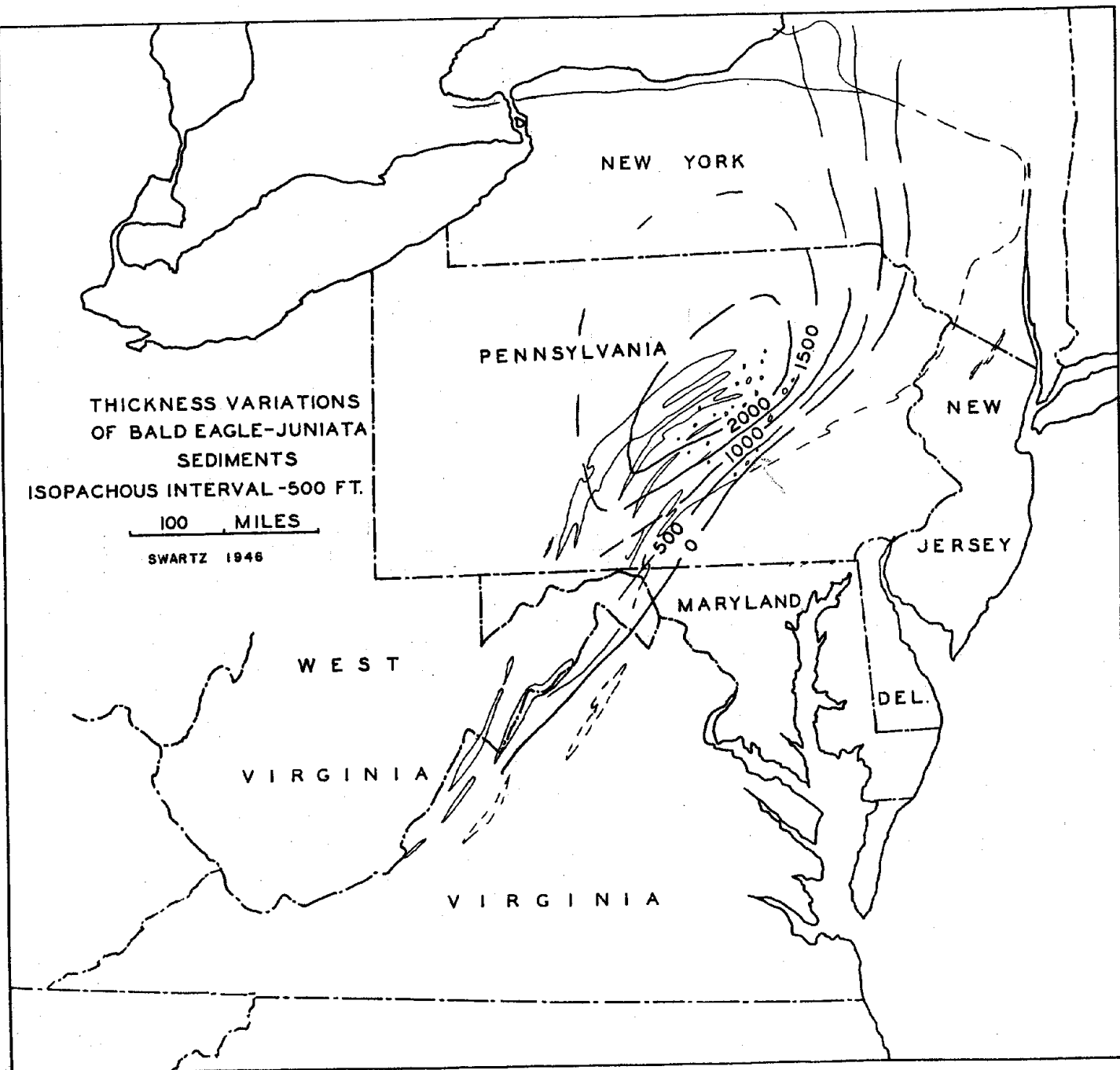
- 112.3 Sand Mt. road on right.
- 112.6-112.7 Sand Mountain, crested by Lost Run conglomerate.
- 112.7-113.6 Descend into anticlinal Decker Valley, with exposures of Reedsville shale.
- 113.7 Gap in Triester Mountain with exposures of Lost Run conglomerate.
- 114.0-114.2 East Waterford red sandstones, in synclinal Triester Valley between Triester and First Mountains.
- 114.5 Gap in First Mountain, with talus from East Waterford and some from Lost Run beds.
- 114.7 Enter Penn Valley at Potters Mills. Turn left on Highway 322; Route 53 on right goes to Pleasant Gap and Bellefonte.
- 114.7 $\frac{1}{2}$  Reedsville shale.
- 115.3 Coburn limestone, in crest of most southeasterly of the three anticlines of the anticlinorium of Penn Valley. The crest of this anticline can be seen in small quarry on south-east side of Route 53,  $\frac{1}{2}$  mile northwest of intersection at Potters Mills.
- 115.6 Antes shale, showing flow cleavage where crumpled in sharp syncline on northwest margin of the anticline previously crossed.
- 116.2-117.8 Reedsville and Antes Gap shales. There are fine views through this general area of the synclinal loop ending Tussey Mountain on south, with anticlinal valley between Tussey and First Mountain on south. To northwest across Penn Valley is synclinal Nittany Valley, the Oswego or Bald Eagle sandstone forming crests at 1800 to 1900 feet, the higher axial backbone of Tuscarora sandstone rising to 2200 feet.
- 118.8-118.9 Type section of Tusseyville limestone at McClellan Chevrolet sign.
- 119.0-121.0 Continuing fine views of Tussey and Nittany Mountains.
- 120.2-120.5 Exposures of Tea Creek dolomite showing characteristic weathering features.
- 124.4 Cross intersection, with Boalsburg on left.

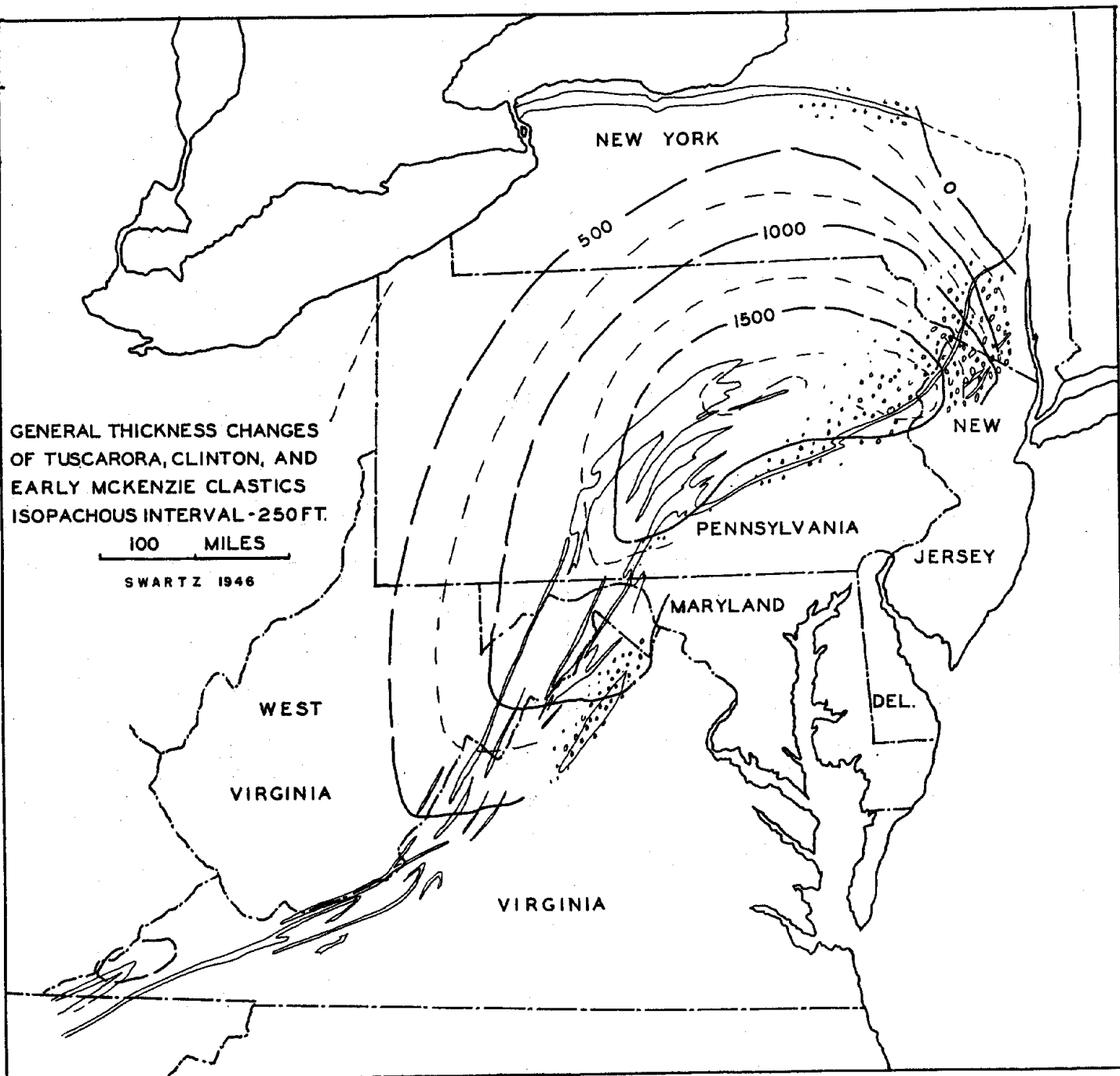
- 124.7      Twenty-Eighth Division Memorial Shrine on right, Birthplace  
            of Memorial Day.
- 127.3      Enter State College. Cross College Avenue at 127.6.
- 129.1      Nittany Lion Inn. End of trip.

THICKNESS VARIATIONS  
OF BALD EAGLE-JUNIATA  
SEDIMENTS  
ISOPACHOUS INTERVAL -500 FT.

100 MILES

SWARTZ 1946

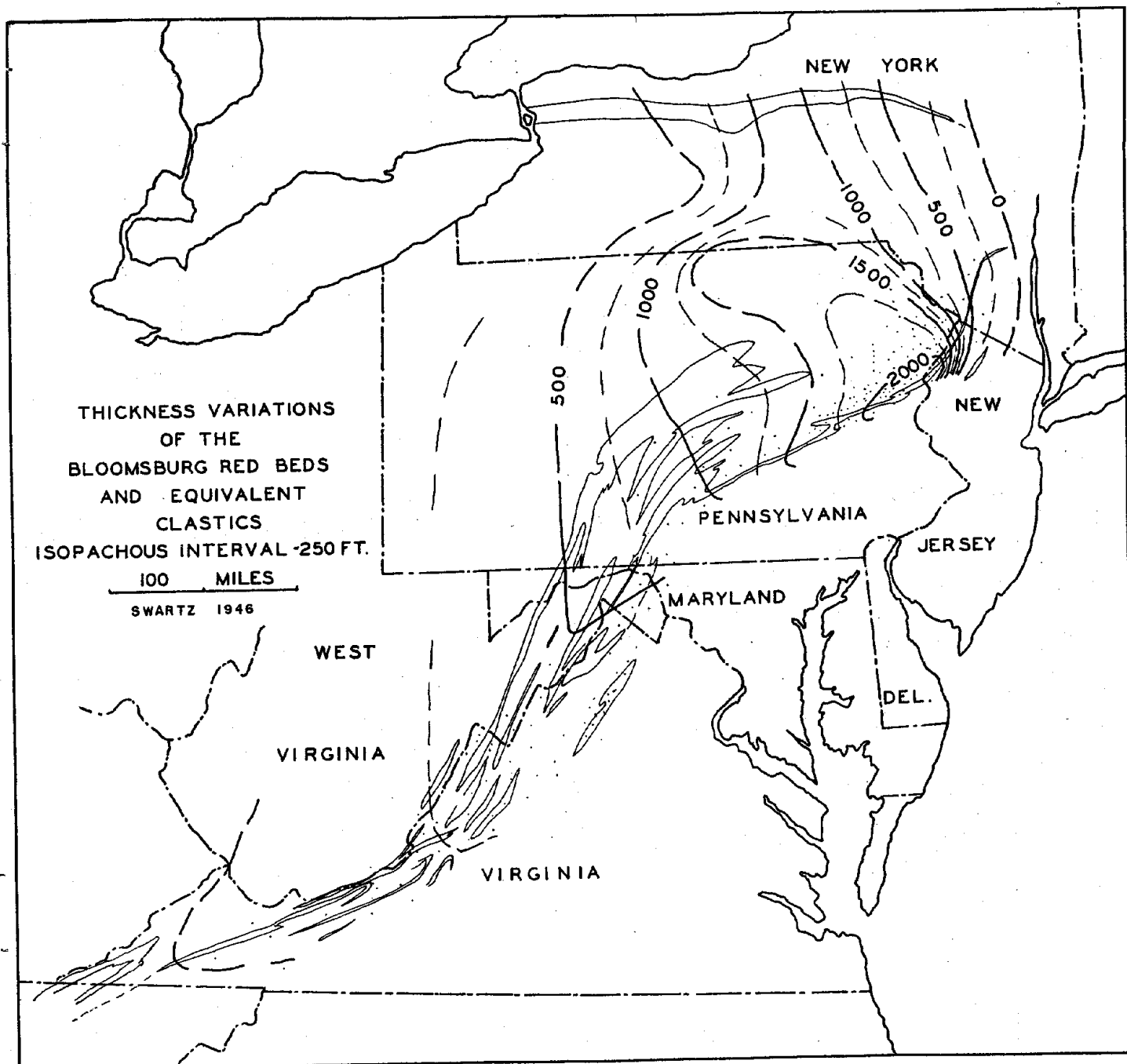


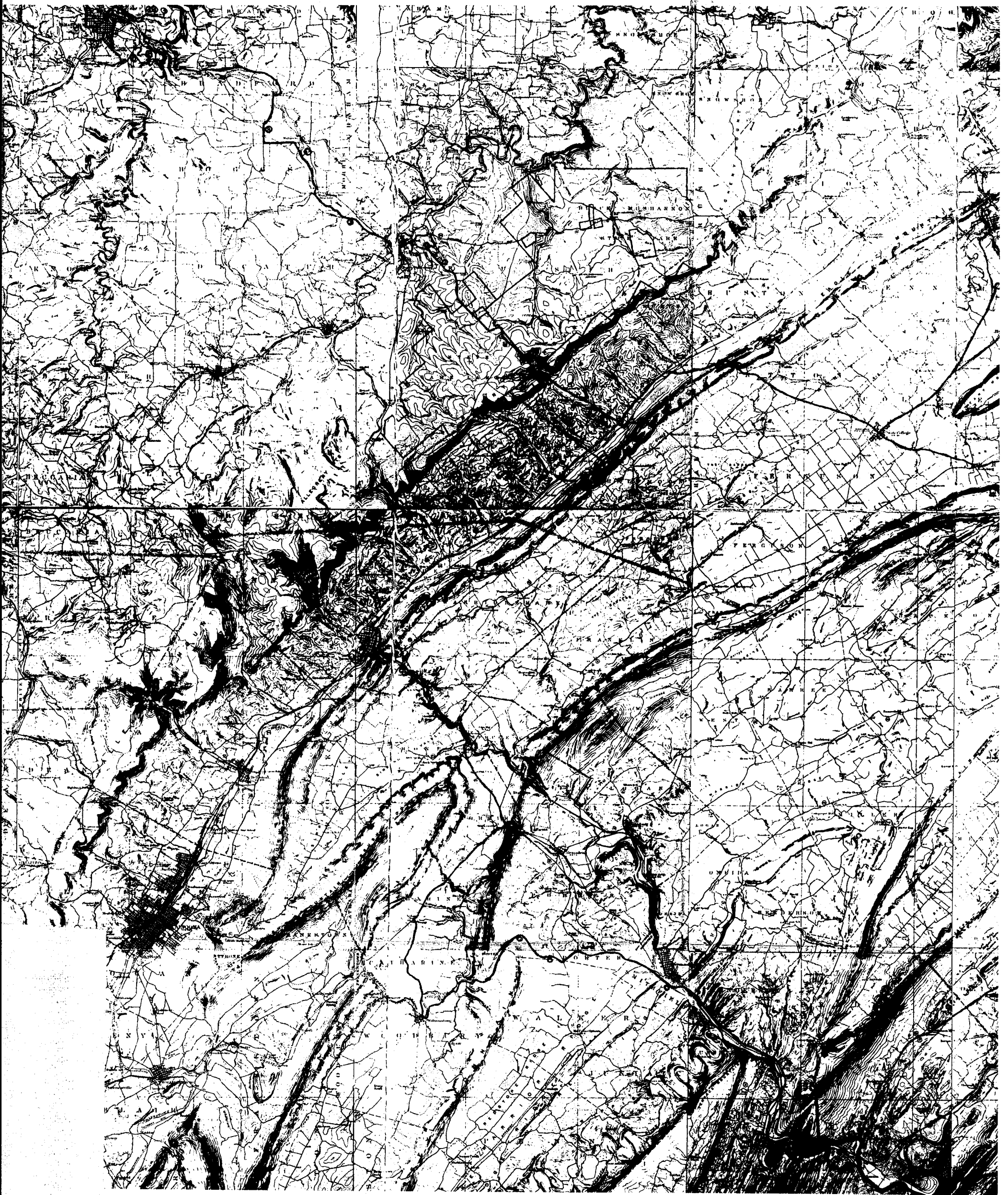


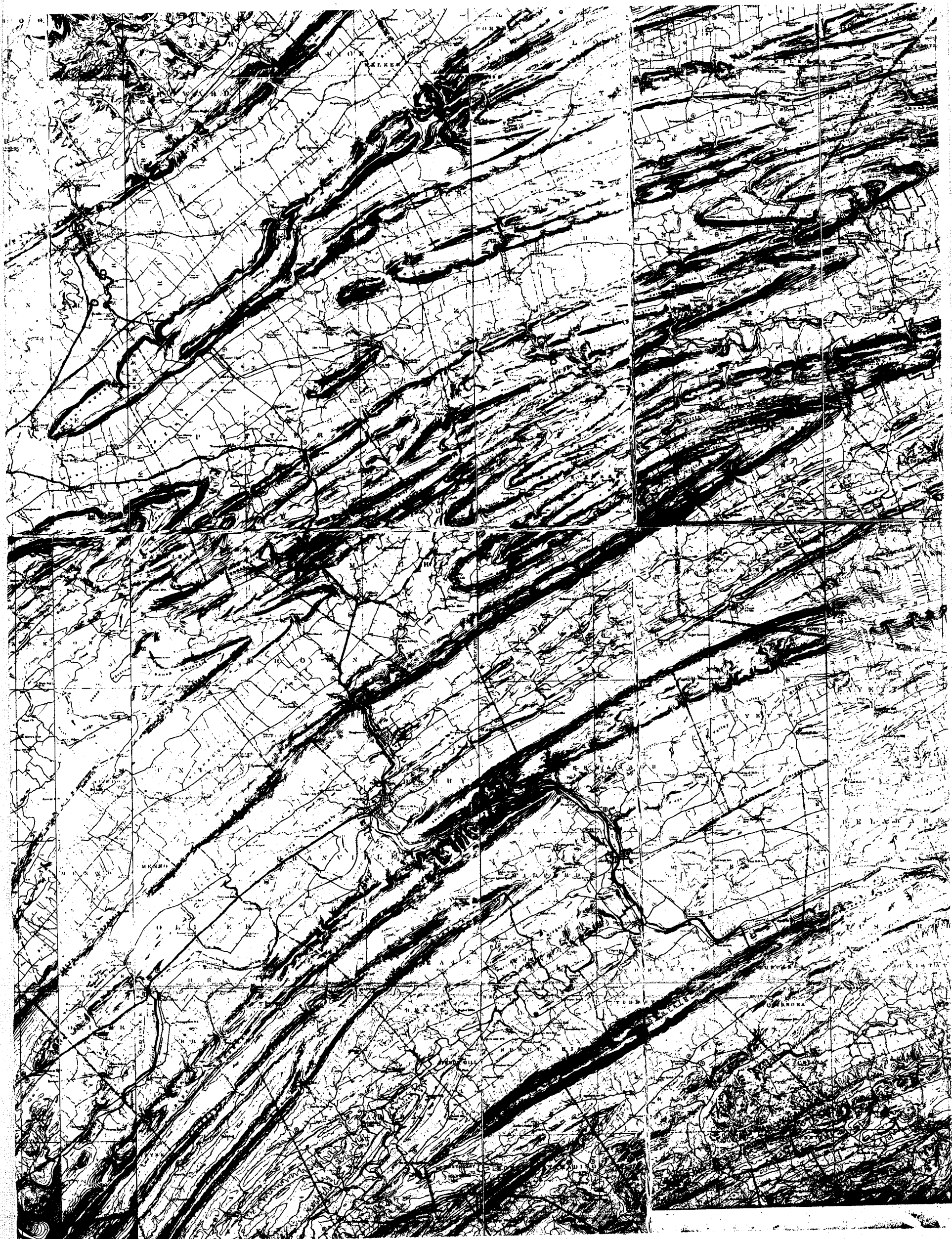
THICKNESS VARIATIONS  
OF THE  
BLOOMSBURG RED BEDS  
AND EQUIVALENT  
CLASTICS  
ISOPACHOUS INTERVAL -250 FT.

100 MILES

SWARTZ 1946







Field Conference of Pennsylvania Geologists

Twenty-First Annual Meeting

May 29, 1955

8 A.M.-2 P.M.

Structure and Stratigraphy of Pennsylvanian  
Sediments of the Plateau area near Philips-  
burg and Clearfield, Pennsylvania

R. P. Nickelsen and E. G. Williams

Introduction

The Philipsburg-Clearfield area lies on the eastern border of the Appalachian Plateau, a region of flat lying or gently dipping Pennsylvanian sediments. This field trip has been planned to illustrate the complex stratigraphy of a small interval of the Pennsylvanian age rocks as well as to present some preliminary data on joint orientations, fault characteristics and the direction of dip of cross-bedding of sandstones of the area.

Bituminous coal and fire clay are produced in the area from strip and deep mines. All good exposures are located in strip mines which follow the outcrop of the essentially flat lying beds and expose 10 to 40 feet of shale and sandstone overburden.



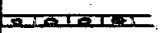




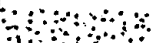





General Stratigraphy - Pennsylvanian system in central Pennsylvania

The following stratigraphic divisions are recognized in the Pennsylvanian system of Pennsylvania:

	<u>Thickness</u>
Monongahela group (or formation)	
Conemaugh group (or formation)	250'
Allegheny group (or formation)	290'
Pottsville group (or formation)	180'

(Thicknesses are average thicknesses  
for Clearfield County according to  
Sisler (1926) p. 164)

In the Philipsburg-Clearfield area no measurable sections of the Pottsville group have been found and the Monongahela and Conemaugh groups are eroded. The field trip is primarily concerned with the stratigraphy of the Allegheny group or "Lower Productive Coal Measures". A classical subdivision of this group into formations (or members) and recognizable prominent coals, sandstones or limestones is given below.

Allegheny Group or Formation	Conemaugh		Mahoning sandstone
	Freeport Formation or Member		Upper Freeport Coal (E)
			Upper Freeport Limestone (Fresh Water)
			Lower Freeport Coal (D)
	Kittanning Formation or Member		Lower Freeport Limestone (Fresh Water)
			Upper Kittanning Coal (C')
			Middle Kittanning Coal (C)
			Kittanning Sandstone
	Clarion Formation or Member		Lower Kittanning Coal (B)
			Boundary at base of clay beneath B coal
			Vanport Limestone (n.p.?) (marine)
			Clarion Coal (A') (n.p.)
			Clarion sandstone
n.p. = not known to be present in this area			Brookville Coal (A)
	Pottsville		Boundary at base of clay

Of the above prominent coals known in the type section of the Allegheny group along the Allegheny river, only the Clarion (A') coal is not thought to be present in this area. However, correlations of all the coals with the type section are open to question and the coal designated as Brookville (A) in this area could well be equivalent to the Clarion of the type area. Generally, the correlations of Sisler (1926) and Ashley (1940) have followed. Emphasis in the early phases of this work has been upon describing what is present in this area, using their designations. After lateral and vertical variations are thoroughly understood in central Pennsylvania, correlation to the type area will be attempted. Similarity in sequence and number of prominent economically important coals indicates approximate equivalence with type sections further west in Pennsylvania. Complex splitting and interfingering over local areas must be understood before exact equivalence can be proven.

### Pennsylvanian Cycle - General

Cyclic repetition of Pennsylvanian sediments was first recognized in the Peoria, Illinois area by Udden (1912). Udden grouped the Pennsylvanian rocks of this area into cycles of deposition using the base of the coal as the plane of separation of the cycles. Weller (1930) introduced the term cyclothem for such deposits in Illinois and established the following ideal cyclothem of 10 members, placing the base of the cyclothem at the base of the sandstone.

10. shale, gray, sandy at top; contains marine fossils and ironstone concretions
9. limestone with marine fossils
8. shale, black, hard, laminated. Most common roof rock of the coal. Contains marine fossils; rich in organic matter.
7. limestone with marine fossils; commonly absent.
6. shale, gray; pyritic nodules and ironstone concretions common at base; plant fossils and marine fossils rare. An uncommon member.
5. coal
4. underclay; medium to light gray, dark gray at top
3. limestone, argillaceous; commonly as nodules or discontinuous beds. Interpreted as fresh water limestone; commonly absent.
2. shale, gray and sandy
1. sandstone, (fine-grained, micaceous) commonly with an uneven lower surface.

Cyclic deposits similar to the type Illinois cyclothem but lacking some of its members and showing expanded development of certain other marine or terrestrial members have been recognized throughout the Appalachian-Central Interior Region of the United States (Wanless and Shepard, (1936); Wanless, (1947)). Wanless and Shepard (1936) have classified the cycles of the Pennsylvanian into piedmont, deltaic and neritic types based upon the relative predominance of marine or terrestrial members.

#### Cycles in the Philipsburg-Clearfield area

Sedimentary cycles similar to those reported in the literature have been recognized in the Pennsylvanian system of this area. An ideal complete cycle in the Allegheny formation of central Pennsylvania consists of the following eight rock types which are discussed in their usual sequence from top to bottom:

8. Clay - may be silty; light olive gray to light gray; plastic when wet or hard flint clay; contains slickensides and root impressions.
7. Limestone - argillaceous, aphanitic; may contain patches of sparry calcite 1-5 mm. in diameter. Dark gray to olive gray when fresh; weathers to yellowish gray; conchoidal fracture; commonly occurs as nodules within clay. Contains ostracodes and gastropods in some places. Generally thought to be fresh-water limestone.
6. Mudstone - If predominantly clay = claystone, If predominantly silt = siltstone, sandy mudstones also occur; light brownish gray to medium gray; structureless - do not break in parallel plates. Commonly are laminated in lower part and grade downward into sandstone or laminated silty and sandy shale. Commonly contain root impressions.
5. Sandstone - fine to coarse grained or conglomeratic; light gray to medium brownish gray; breaks into platy or flaggy fragments; commonly cross-bedded and containing fragments of tree trunks now converted to coaly partings. These sandstones are low rank or sub-graywackes containing abundant mica, rock fragments and clay matrix. Sorting is poor and particles angular.

4. Shale - laminated silt and very fine sandy; light gray laminations are fine sand to silt; medium gray to medium dark gray laminations are silt to silty shale; laminations 1 to 2 mm. Breaks into flat pieces 4-10 mm. thick; small scale cross-bedding and ripple marks common; plant fragments fairly abundant.
3. Shale - silty to clay; medium dark gray to grayish black; laminations 2-4 mm. and indistinct or not present; commonly breaks into flat pieces 1 to 4 mm. thick; pieces may also be subconchoidal or hackly, having roughly equidimensional or subrectangular shape; may contain ironstone concretions or beds up to 25%. May contain marine or brackish marine brachiopods, fresh-water mollusks, marine molluscs and assorted plant fragments.
2. Shale - clay to silty; carbonaceous; black to gray black; papery fracture in plates 1 mm. thick; plant impressions and coaly partings common.

1. Coal

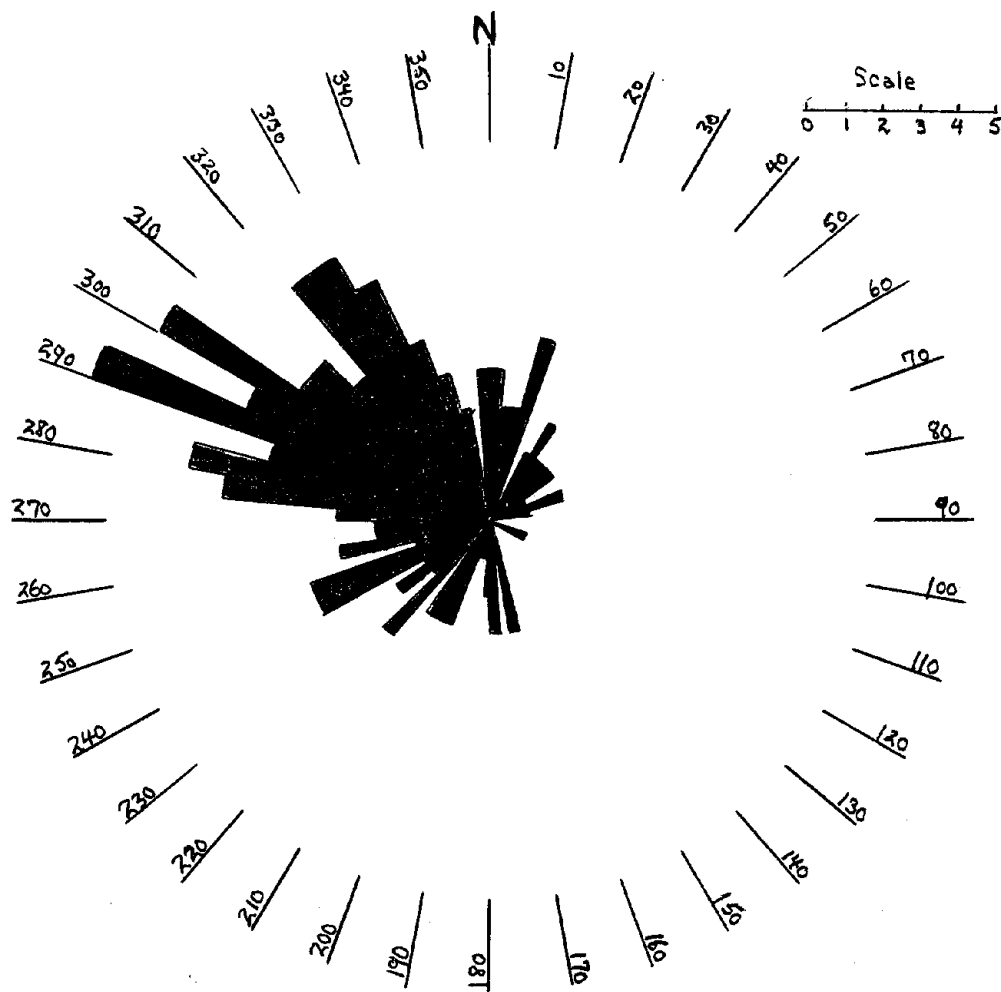
### Cross-bedding

The direction of cross-bedding in sandstones of the Philipsburg-Houtzdale syncline has been measured and plotted on the rose diagram appearing on the following page. Where possible observations on two cross-beds within each set of cross beds present at the exposure were recorded. Number of sets of cross-beds varied from 1 to 6. Observations from the following sandstones are included in the rose diagram:

- a) Clarion sandstone above the Brookville coal ("A").
- b) Kittanning sandstone above the Lower Kittanning coal ("B").
- c) A local sandstone between the Lower Kittanning "B" and "B-1" coals.
- d) A local sandstone above the Middle Kittanning "C" coal.
- e) Mahoning sandstone above the Upper Freeport "E" coal.

Cross-beds in these sandstones dip dominantly west indicating sediment transport in this direction. This is in accord with classical ideas regarding origin of Pennsylvanian sediments from the east or southeast. Actually, the data has little significance until work is completed over a larger area and the individual sets of readings are plotted in their map location. Mapping and correlation of sandstone bodies must be completed before this can be done.

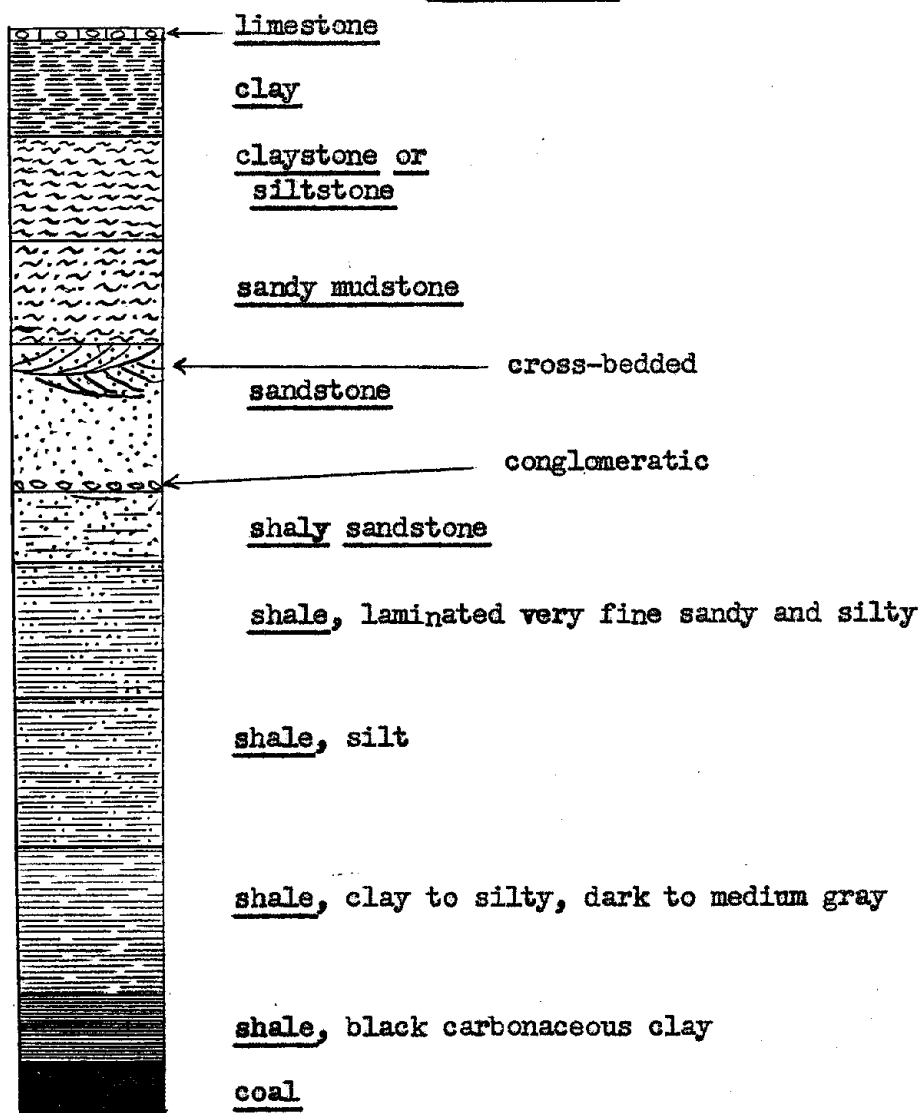
Space does not permit the publication of separate rose diagrams for each of the sandstone bodies from which readings were taken. In preliminary plots, dip directions seem to vary around different means for each of the sandstones. In the Mahoning sandstone over an area of several square miles all dips are in the northeast and northwest quadrants. Dips in the Kittanning sandstone likewise are predominantly northward with a concentration in the northwest quadrant. In the local sandstone above the "C" coal all dips are concentrated in the northwest and southwest quadrant. It is hoped that as work progresses such data will prove useful in showing trends of individual sandstone bodies and suggesting directions of sediment transport. When completed over a large area and coupled with petrographic data on the sandstones it may be helpful in suggesting source of sediments.








Rose diagram showing cross-bed dip directions in sandstones of the Philipsburg-Houtsdale syncline (198 observations)

Symbols Used Throughout Text and Figures

Rock Symbols



Fossil Symbols

-  9T — Plant impressions
-  9L — Lingula -brackish- marine?
-  9P — Fresh-water pelecypods, Naiadites?
-  9M — Marine - brackish water pelecypods  
Aviculopecten?
-  9B — Marine brachiopods

## General Structure of the Philipsburg-Clearfield Area

The field trip will cross three major structures in the gently warped sediments of the Appalachian Plateau.

Coal producing area lying on a northeast-southwest trend passing through Philipsburg and Houtzdale are located in the Philipsburg-Houtzdale syncline or "Philipsburg basin". Here coals of the Allegheny group, and, in one known case, the lowermost Conemaugh are mined. The Laurel Hill anticline, passing northeast-southwest through Bigler, Pennsylvania, borders the Philipsburg-Houtzdale syncline on the northwest and brings the Pottsville group to the surface although lower Allegheny coals and clays are mined and stripped extensively on its axis. The third major structure of the region is the Clearfield syncline which is deepest along an axis trending northeast through Clearfield, Pennsylvania. Along the Susquehanna River near Clearfield, all the Allegheny coals except the Brookville (A) coal are stripped or mined. South of the river where relief is less only the upper Allegheny coals are worked and remnants of the lower Conemaugh are present. Location of anticlinal and synclinal axes is taken from Ingham (1951) and Fettke and Fairall (1953).

## Joints

The strike of the joints present in the rocks of the Appalachian Plateau in the Houtzdale-Phillipsburg area is concentrated in several maxima as indicated in the figure on the next page, a composite rose diagram of joint strike orientations of 295 joints. At all localities where jointing was well-developed 5 observations were taken on each joint set and the results plotted on the composite rose diagrams representing the whole area of work. At some localities 5 observations could not be made on certain joint sets, due to their poor development, and as many joints as possible were measured. Since all joints in the area are vertical or nearly vertical, dip was not recorded in order to speed up field observation.

Composite rose diagrams of joints in the area bear out the general impression of joint orientation gained from several outcrops where all sets are present. The following 4 joint sets are recognized on the basis of this preliminary data:

- a) a set striking between N30W and N45W
- b) a set striking between N45E and N60E
- c) a set striking between N10W and N20W
- d) a set striking between N60E and N100E (N80W)

Joints are present in the coal and in the shales and sandstones overlying the coal. Joints in coal are commonly called cleat.

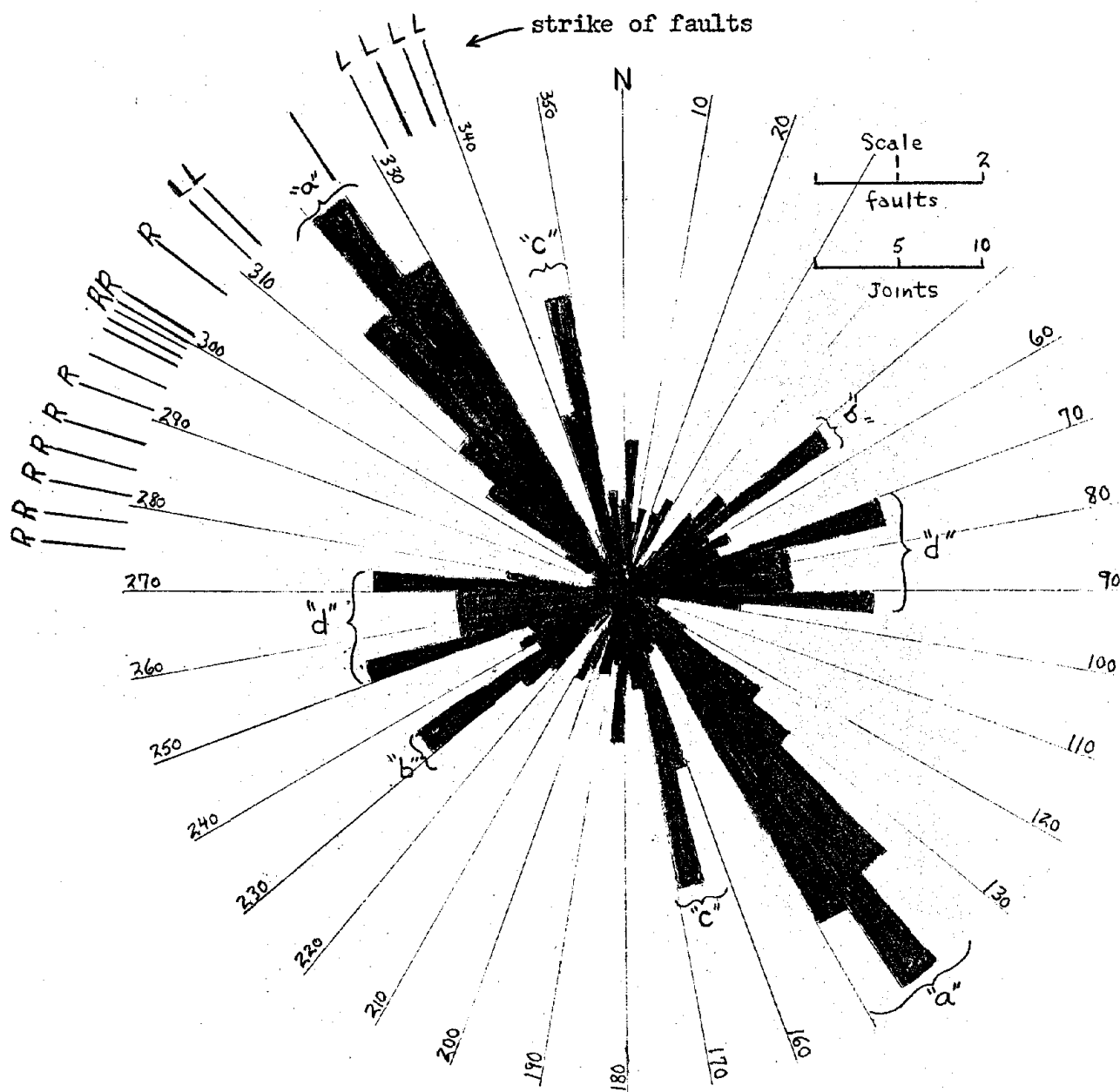
Some of the joint sets possess characteristics which serve to distinguish them before their orientation is measured. The most common and best developed joint is the "a" set, striking between N30W and N45W. This set is characterized by smooth, almost perfectly planar surfaces which rarely vary more than 5 degrees in strike within any one outcrop. The "b" joint set, striking between N45E and N60E, is characterized by highly irregular sub-conchoidal fractures which vary considerably in both dip and strike within one outcrop. The joint surface is much rougher than that of the accompanying "a" set. The "c" and "d"

sets are present only in the coal and dip uniformly at angles close to  $90^\circ$ , but vary greatly in strike.

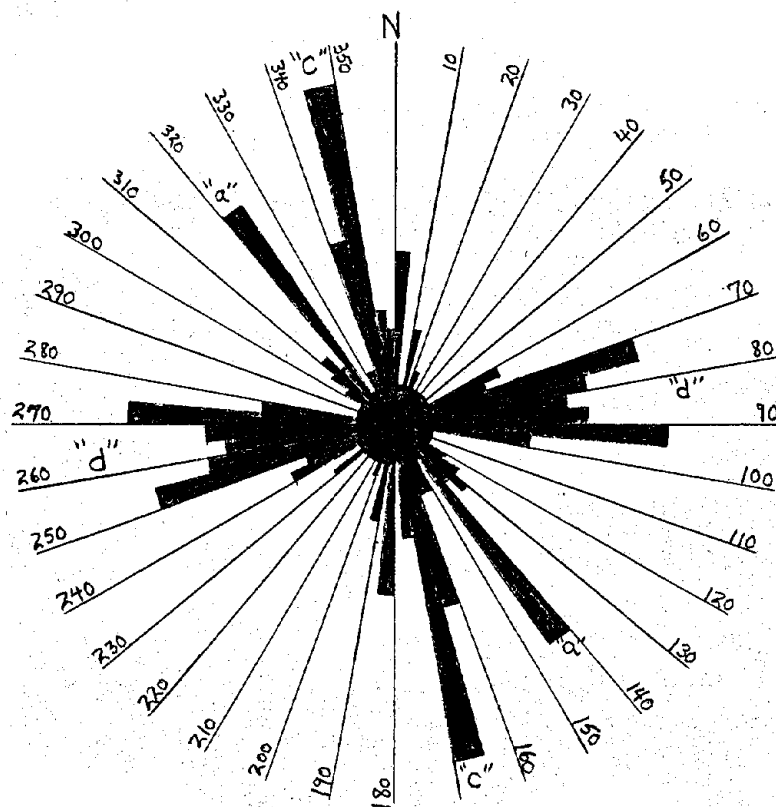
Rose diagram showing strike orientation of joints and faults in the Philipsburg-Houtzdale syncline.

L - left-handed faults

R - right-handed faults

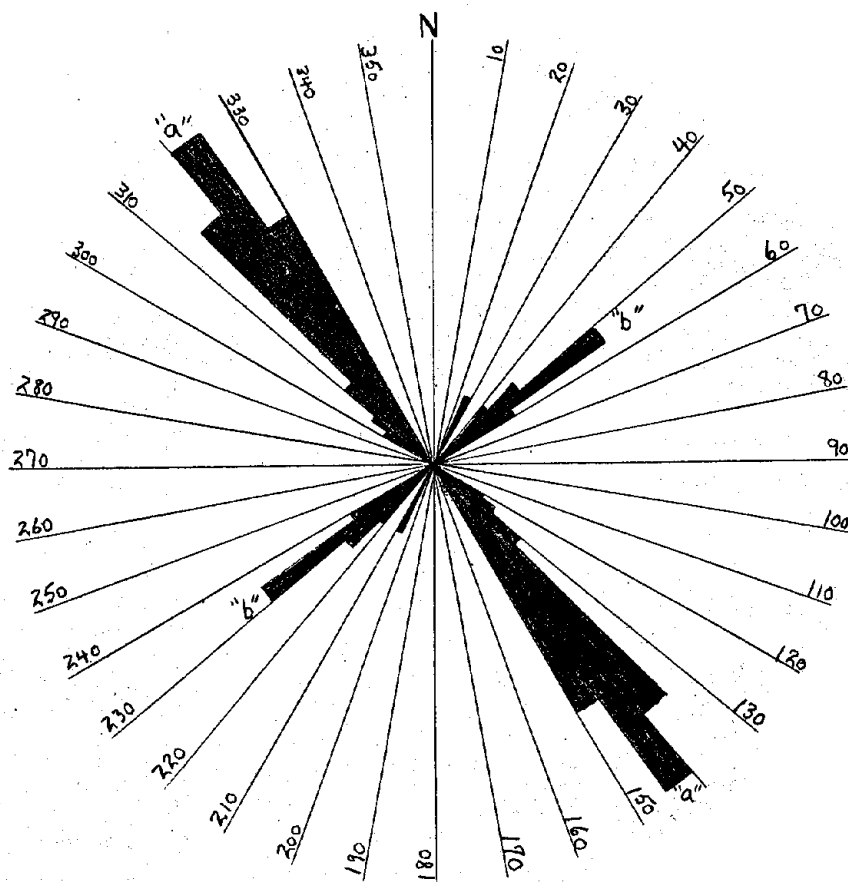


A further breakdown of the maximum orientations based upon rock type is shown in the accompanying figures. Here it is apparent that joint maxima "a"



Joint strike orientations in coal of the  
Philipsburg-Houtzdale syncline.

and "b" are well-developed in the shales and sandstones above the coal while maxima "a", "c" and "d" are present in the coals. To summarize the orientation of the maxima, the pattern may be thought of as consisting of 2 conjugate joint systems, each composed of 2 sets of joints meeting at angles of 80 or 90 degrees. The system comprising the "a" and "b" joint sets is largely restricted to the shales and sandstones above the coal but the well-developed "a" set also appears in the coal, commonly only in the upper part of the bed. The system composed of sets "c" and "d" is restricted to the coals and rotated 25 or 30 degrees in a clockwise direction from the "a" - "b" system. Interpretation of possible tectonic significance of these joint patterns will have to await more widespread regional orientation studies and a more rigorous statistical treatment of the significance of maximum orientations indicated by this preliminary data.



Joint strike orientations in shales and sandstones  
of the  
Phillipsburg-Houtzdale syncline.

The following relationships with joint sets in the folded Valley and Ridge province to the Southeast have been observed. The "a" set of the Appalachian plateau is similar in orientation and character of the joint surface to the cross or dip joints present in the folded rocks of the Valley and Ridge. The "b" set is similar in orientation and character of breaking to the strike or longitudinal joints in the western part of the Valley and Ridge. Insufficient work has been done on joint sets in the Valley and Ridge to know whether there are counterparts of the "c" and "d" joint sets in some of the rocks of that area.

## Faults

Faults observed so far in the Philipsburg-Houtzdale-Clearfield area are essentially vertical and have large strike slip components of movement. Ashley (1928, p. 73) reports similar faults from the Houtzdale area. The first figure of this section shows the strike orientation of 20 faults.

Most faults show some dip slip displacement of coal beds or other strata when viewed in cross section. Inspection of the fault plane may reveal slickensides, rarely plunging more than 10 or 15 degrees, which indicate the probable direction of net slip along the fault. Where slickensides are clear and uniformly developed and direction of relative dip slip can be seen in an intersected bed it is possible to classify the fault as having right-handed (dextral) or left-handed (sinistral) strike slip movement. Left-handed faults in the figure strike between N20W and N48W while right-handed faults strike between N52W and N85W.

Right-handed and left-handed strike slip movement along faults oriented as shown in the figure will result in shortening in a northwest-southeast direction and lengthening in a northeast-southwest direction. Considerable distortion may have resulted from small movements along a large number of faults. Unfortunately, no quantitative estimate of the number of these faults can be made. Faulting and the warping of beds into broad anticlines and synclines is the only known expression in the Appalachian Plateau of the stress that sharply folded the adjacent Valley and Ridge province.

E.M. Anderson (1951) analyzed fault patterns in Great Britain and concluded that sets of high-angle strike slip faults result when the regional least and principal stress axes are horizontal and the intermediate stress axis is vertical. The principal stress axis bisects the acute angle between sets of right-handed and left-handed high angle strike slip faults.

The same analysis can be applied to the preliminary data from this region. As might be expected from the orientation of fold axes in the adjacent Valley and Ridge, the principal stress axis strikes northwest (approximately N50W) bisecting the acute angle between the left-handed and right-handed faults. The least stress axis strikes northeast and the intermediate stress axis is vertical. More data on the orientation of both faults and joints must be collected before the plan of deformation in the region will be completely understood. The foregoing is included as an illustration of the types of minor structures available for investigation in a region of only slight deformation.

Trip #3

Sunday, May 29, 1955

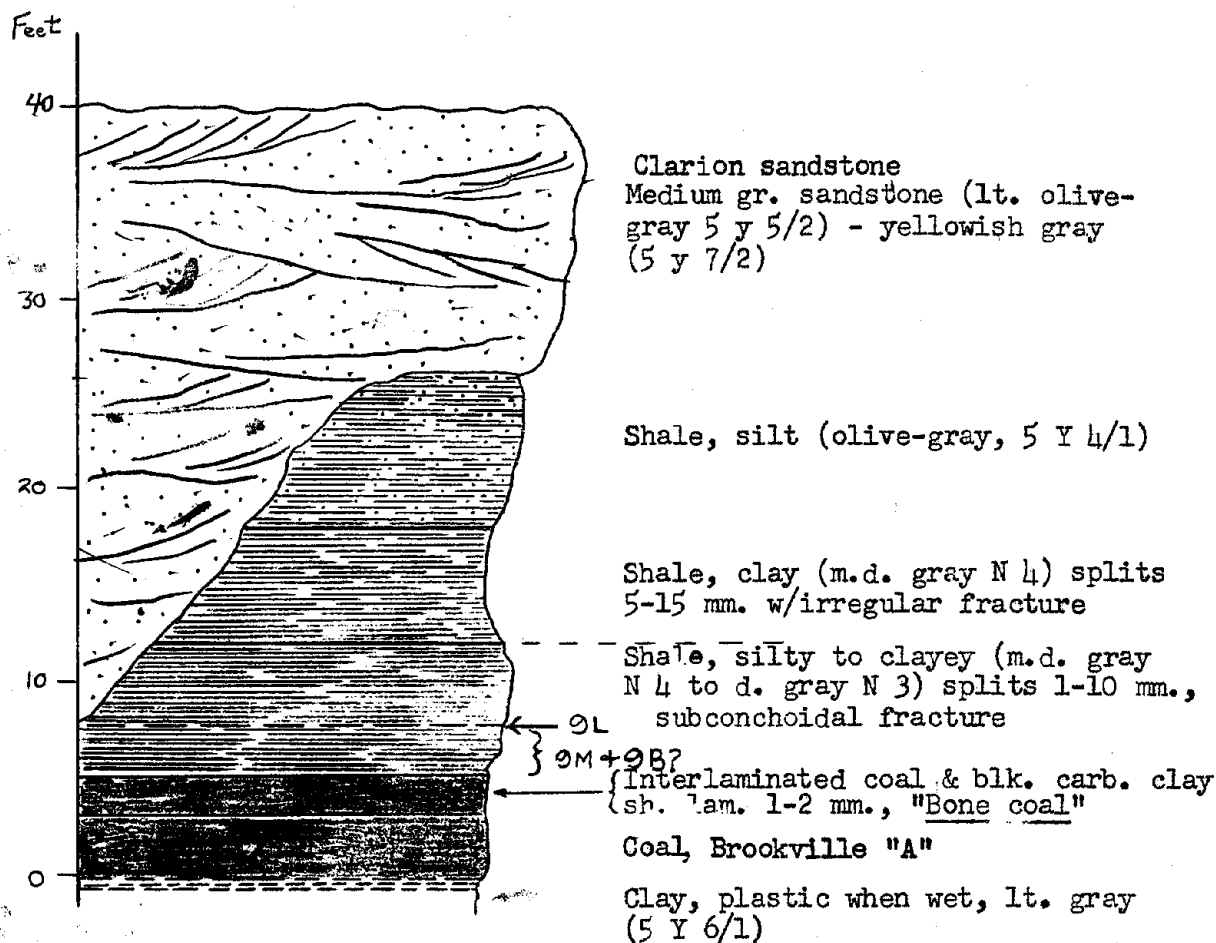
Departure: 8:00 A.M., by bus and private car from parking area #11 near tennis courts southeast of Nittany Lion Inn.

ItineraryMiles

- 0.0      Go west on Route 322 past Nittany Lion Inn.
- 5.8      Ascending Bald Eagle Mountain, westernmost ridge in the Valley and Ridge Province. Reedsville Shale (M. - U. Ordovician), Oswego Sandstone (U. Ordovician) and red and green Juniata shale and sandstone (U. Ordovician) in road cuts on right of road.
- 6.3      Summit of Bald Eagle Mountain. View of Allegheny Front to the west. Tuscarora quartzite (L. Silurian) in roadcut on left.
- 8.7      Stop sign. Junction of Route 322 and 220. Continue on Route 322.
- 10.1-10.4 Large road cuts of Brallier shale (Upper Devonian) on right. Bedding dips 40-60 degrees northwest. Note two prominent joint sets in this outcrop. Dip joints are vertical and form smooth surfaces striking perpendicular to road; strike joints are perpendicular to bedding and are irregular surfaces on the face of the outcrop parallel to the road. These joints are characteristic of the folded rocks of the Valley and Ridge province and have counterparts in the essentially flat lying rocks of the Appalachian plateau.
- 11.0      Entering Port Matilda.
- 11.5      Turn right on Route 322 in center of Port Matilda.
- 11.8      Leaving Port Matilda. View toward Allegheny Front.
- 14.4-14.7 Red sandstone and shale of the Catskill formation (U. Devonian) in road cuts on right.
- 15.9      Roadcut exposing Pocono sandstone (Mississippian) on right.
- 16.5      Summit of Appalachian Plateau. High tension power line to right of road. Approximate Pocono sandstone - Pottsville sandstone and conglomerate contact.

- 21.9 STOP 1: Park off the pavement along right side of Route 322, facing west. Walk 100 feet north along dirt road entering Route 322 to see exposure of the Brookville Coal ("A" coal) and overburden in a strip mine.

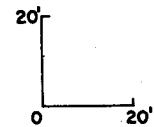
# Section of A Coal and Overburden



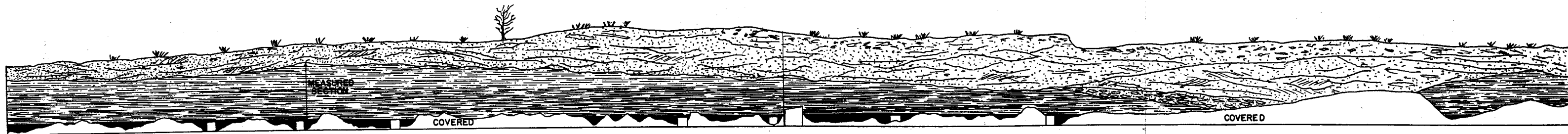
Very poorly preserved faunal remains have been collected in the shales within 3 feet above the coal. At 3 feet above the coal Lingula sp.?, indicating brackish-water environment, is present and below this point fragments of possibly marine or brackish water pelecypods and brachiopods (?) have been found.

STOP 1 — SKETCH OF CHANNEL IN BROOKVILLE COAL STRIP MINE

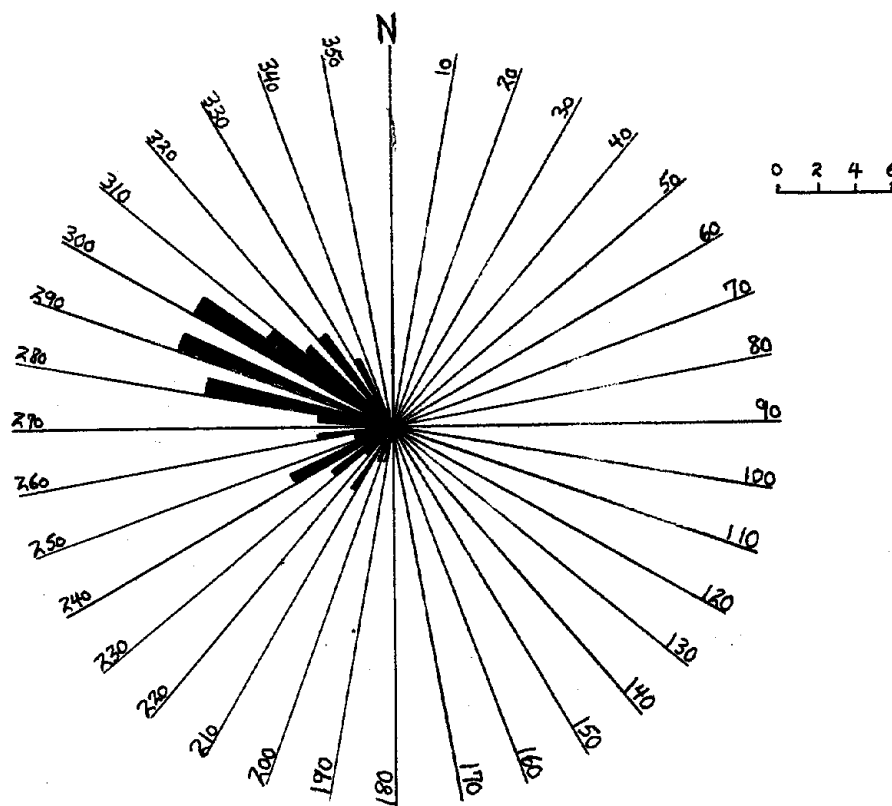
HOR. & VERT. SCALE —



AZIMUTH 384° →



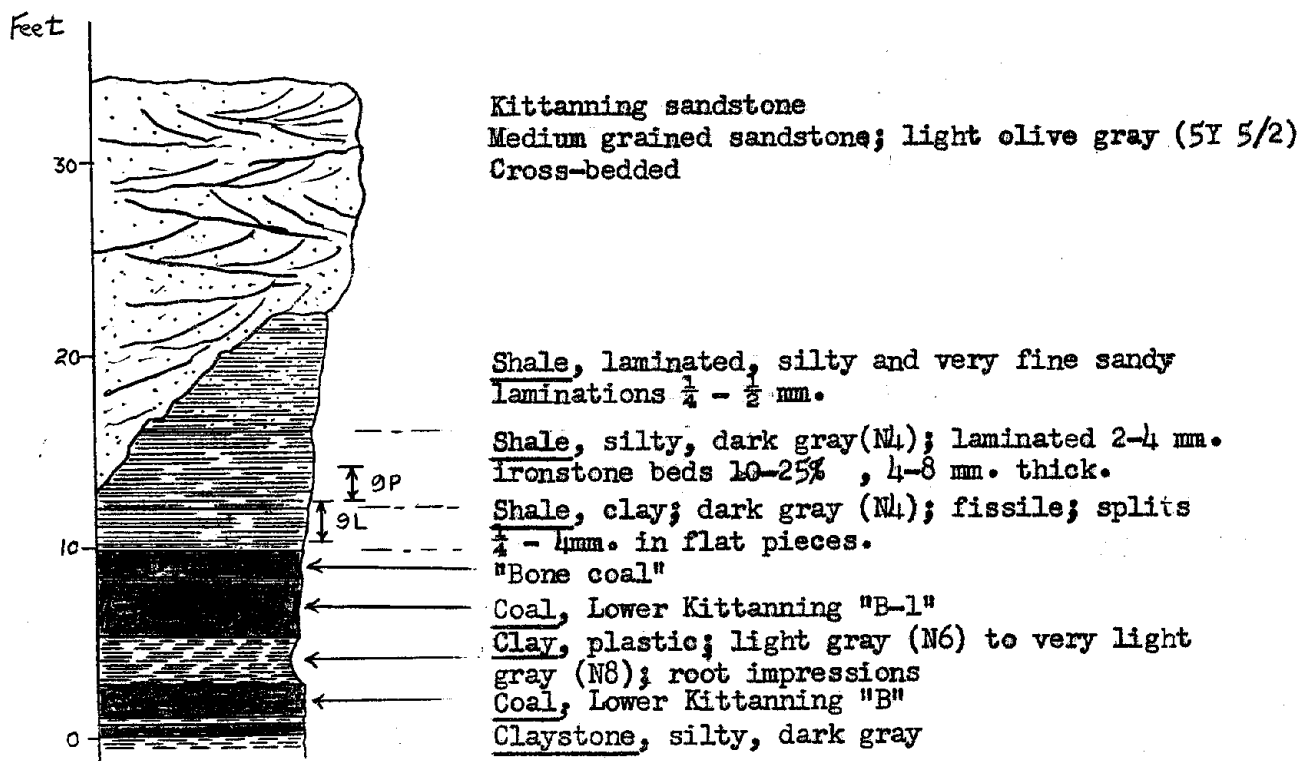
See "Sketch of Channel in Brookville Coal Strip Mine" for illustration of sandstone-shaly overburden relationships which may be observed here. Section 4 of the Fence Diagram was measured at the north end of this strip mine. On the Fence Diagram you will note that this locality is near the northeast side of a large body of sandstone (the Clarion sandstone?) which occurs above the Brookville ("A") coal from here to a point near Houtzdale, 10.5 miles to the southwest. At all sections within this area, the sandstone disconformably overlies the shale and coal. Southwest of section 12 on the Fence Diagram no channel sandstone is present in this position. Northeast of this stop the sandstone is not present or is less than 10 feet thick in the few sections that have been visited. Insufficient work has been done on the northwest side of the Philipsburg basin to delimit the trend of this sand body. Direction of cross-bedding dip measurements indicates a general westerly trend of sediment transport with some concentration of dip directions between N 50 W and N 80 W (see below).



Rose diagram showing cross bedding dip directions  
in Clarion sandstone (?) in Philipsburg basin  
(52 observations)

- 22.7 Turn right on dirt road leaving Route 322 just beyond Motel.  
Dirt road marked by sign "House Coal", "B" seam.
- 22.9 STOP 2: Park on dirt road and walk into strip mine exposing  
Lower Kittanning ("B") coal and overburden.

The section below was measured at the far end of the Strip Mine



A sandstone channel similar to that at Stop 1 is exposed here. This sandstone is the Kittanning sandstone, a prominent sand body in many areas in west central Pennsylvania. As shown on the Fence Diagram it is present only in the northeastern part of the Philipsburg basin, north of this stop. Work has not progressed far enough northward and westward to delimit the boundaries or trend of this sandstone. Section 4 on the Fence Diagram which is a composite of what is seen at Stops 1 and 2 shows that these stops are on the northeast margin of the Clarion

sand and the southwest margin of the Kittanning sand.

Compaction in areas of thick accumulation of the Clarion sandstone was probably not as great as in areas where the overburden of the Brookville coal was largely shale. It is suggested that the thick Clarion sand had an effect upon the position of deposition of the Kittanning sandstone, forcing the delta distributary or river which channeled the shales and deposited the Kittanning sandstone into a more northeasterly position. The horizon of this sandstone in the complete, unchanneled, sections of the Lower Kittanning coals and rider coals to the southwest is not known.

The "B" coal at this stop is split into 2 "benches" separated by a  $2\frac{1}{2}$  foot clay bed. The regional significance of this split will be pointed out during the rest of the trip. As an introduction, a glance at the Fence Diagram will show that the interval between the two "B" coal benches varies from 0 to over 20' when traced throughout the Philipsburg basin. Generally, on the eastern side of the basin the benches are close together and separated only by a few inches of clay. Westward the interval increases and is either occupied by a thick, economically important clay or a complete cycle of sedimentation, comprising shale, sandstone and clay or mudstone.

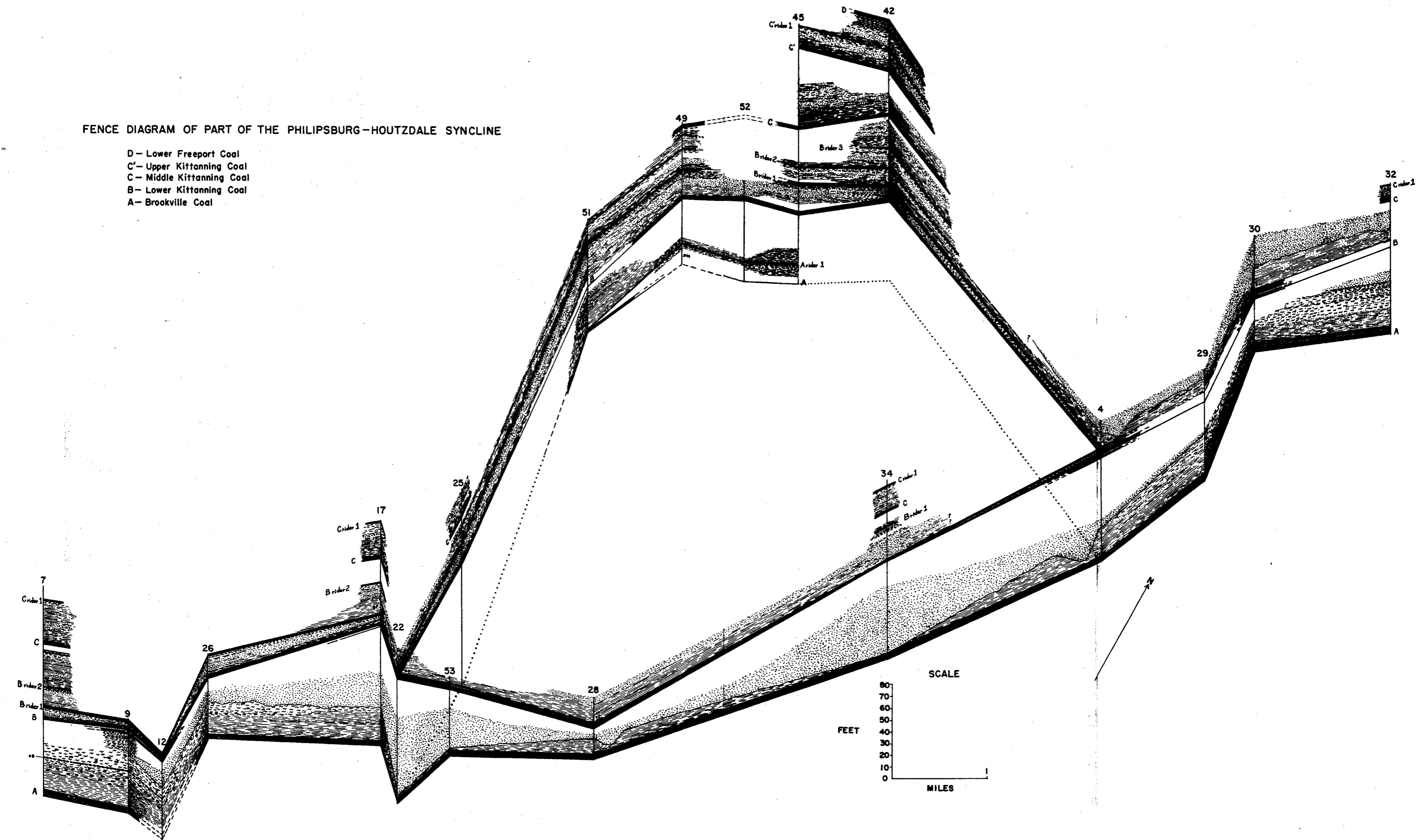
Zonation of brackish marine and fresh water fossils is well developed at this stop. As shown in the section *Lingula* sp? is restricted to a zone extending approximately from 6" to  $2\frac{1}{2}$ ' above the coal. Fresh water molluscs are found from  $2\frac{1}{2}$ ' to 4 or 5' above the coal.

Two joint sets are developed at the far end of the strip in both the coal and shale. Smooth regular breaks oriented parallel to the strip are the "a" joint set corresponding in orientation and character to dip or cross joints of the Valley and Ridge. Irregular breaks perpendicular to these are the "b" set, similar to the strike joints of the Valley and Ridge.

- 23.6     Turn left on paved highway at Stop Sign on route 504.
- 24.5     Junction with route 322. Straight ahead on route 322. Entering Philipsburg.
- 25.1     Traffic Light. Turn right following route 322.
- 25.3     Red blinker light. Turn left following route 322.
- 25.5     Traffic Light. Turn right following route 322.
- 26.1     Turn left oblique on paved road leaving route 322. Strip mine in Upper Kittanning coal to left of intersection.
- 26.7     Strip mines in Middle and Upper Kittanning and Lower and Upper Freeport coals on hill to left of road.
- 27.5     STOP 3. Park along paved road facing west or drive short distance in on dirt road entering from the south. Walk into strip mine exposing section of Lower Kittanning coals.

# FENCE DIAGRAM OF PART OF THE PHILIPSBURG-HOUTZDALE SYNCLINE

- D - Lower Freeport Coal
- C' - Upper Kittanning Coal
- C - Middle Kittanning Coal
- B - Lower Kittanning Coal
- A - Brookville Coal



27.5 STOP 3: Park along paved road facing west or drive short distance in on dirt road entering from the south. Walk into strip mine exposing section of Lower Kittanning coals.

The base of the attached section is in the Lower Kittanning strip mine. The remainder of the section was measured eastward to the top of the hill where the Lower Freeport "D" coal is exposed. This is one of the most complete accessible sections in the Allegheny formation of the Philipsburg-Houtzdale syncline. The stop was chosen to illustrate rock bodies, and the cyclic character of the sediments and to demonstrate lateral variation in the Lower Kittanning "B"- "B-1" coal interval.

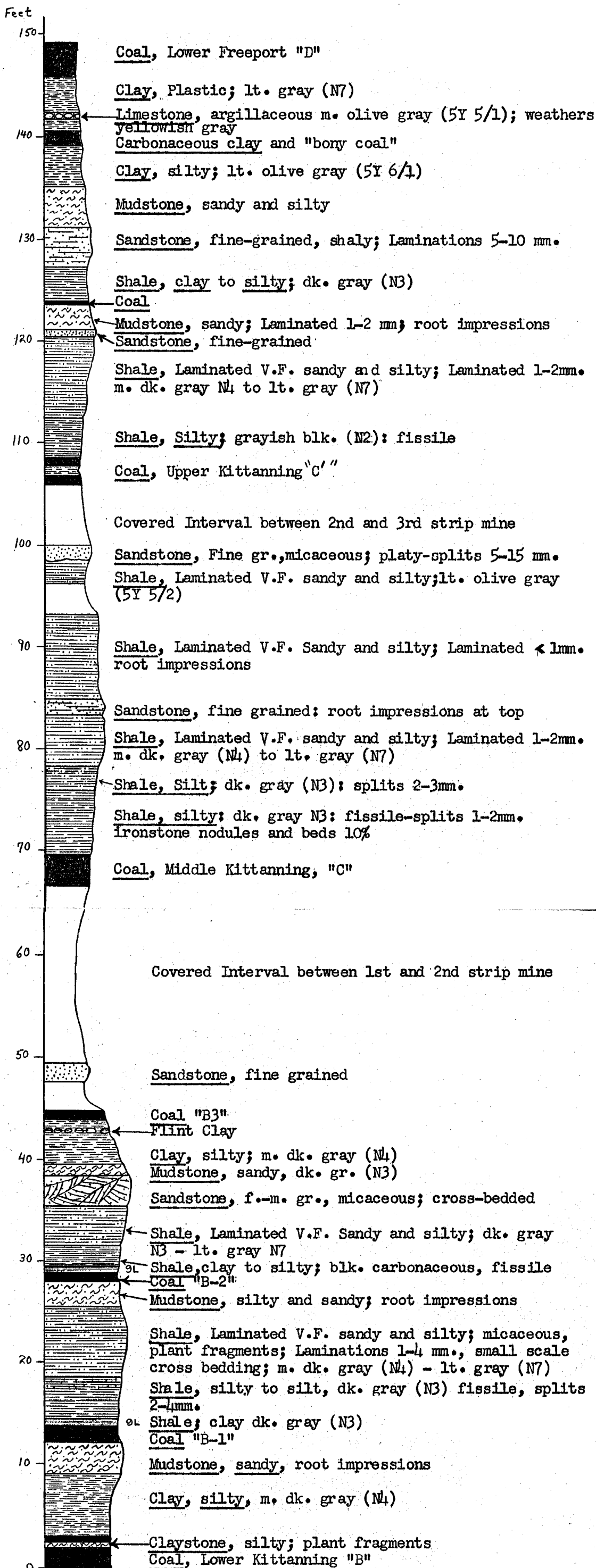
#### Discussion of Section

The "B" and "B-1" coals are here separated by an interval of 9 feet of silty clay and mudstone. These coals are equivalent to the two benches of the Lower Kittanning coal seen at Stop 2. Equivalence has been established by mapping and lateral tracing of key zones. The "B-2" and "B-3" coals seen in the high wall of this strip mine were not present at Stop 2 owing to non-deposition or channeling associated with the Kittanning sandstone.

The stop affords an opportunity to observe the cyclic repetition of rock types discussed in the INTRODUCTION. Seven cycles or parts of cycles are exposed in this section. Proceeding up section every coal except the "B" coal is seen to be overlain by fissile, dark gray clay to silty shales, followed by laminated silty and very fine sandy shales containing abundant fragments of plants. Sandstone is not present above the laminated shales at all points in every cycle but in most cycles may be found in this position by walking along the strip mine. The contact with the laminated shales varies from conformable to disconformable. Above the sandstone or laminated shale, mudstone is present in most places and is commonly penetrated by root impressions. If clay is present in the cycle it occurs above the mudstone. Fresh-water limestone, such as occurs in this section beneath the "D" coal, may be present within the clay.

This stop and succeeding ones illustrate that thick sandstone bodies with disconformable lower contacts such as seen at Stops 1 and 2 are the exception rather than the rule in the Allegheny formation of this part of Pennsylvania. Volumetrically, they occupy only a small part of the total sequence although they are prominent in certain cycles in certain areas (See Fence Diagram).

## Stratigraphic Section at Stop 3



## Lateral Changes in the "B"- "B-1" Coal Interval

By walking southwestward along the Lower Kittanning strip mine, a part of the lateral variation in the "B"- "B-1" coal interval, illustrated in the Fence Diagram (Sections 42, 44 and 52), may be seen. At Stop 3 the "B"- "B-1" coal interval is composed of silty clay and mudstone with only a suggestion of cyclic sedimentation. This same interval at Stop 2 contains  $2\frac{1}{2}'$  of plastic clay.

One-quarter mile southwest of Stop 3 the "B"- "B-1" coal interval is 15 feet. Here it is cyclic, composed of laminated claystone above the "B" coal grading upward into 3 feet of medium-grained sandstone. Sandy mudstone and plastic clay occur between the sandstone and "B-1" coal. As shown on the Fence Diagram, (Sections 44 and 45), further to the southwest the cyclic character of this interval is more pronounced. Still further southwest, at Section 52 on the Fence Diagram, the whole interval is occupied by medium to coarse-grained sandstone which apparently interfingers laterally in both directions with a normal cycle.

Two general points are illustrated by the "B"- "B-1" coal interval between Stop 2 and Stop 3.

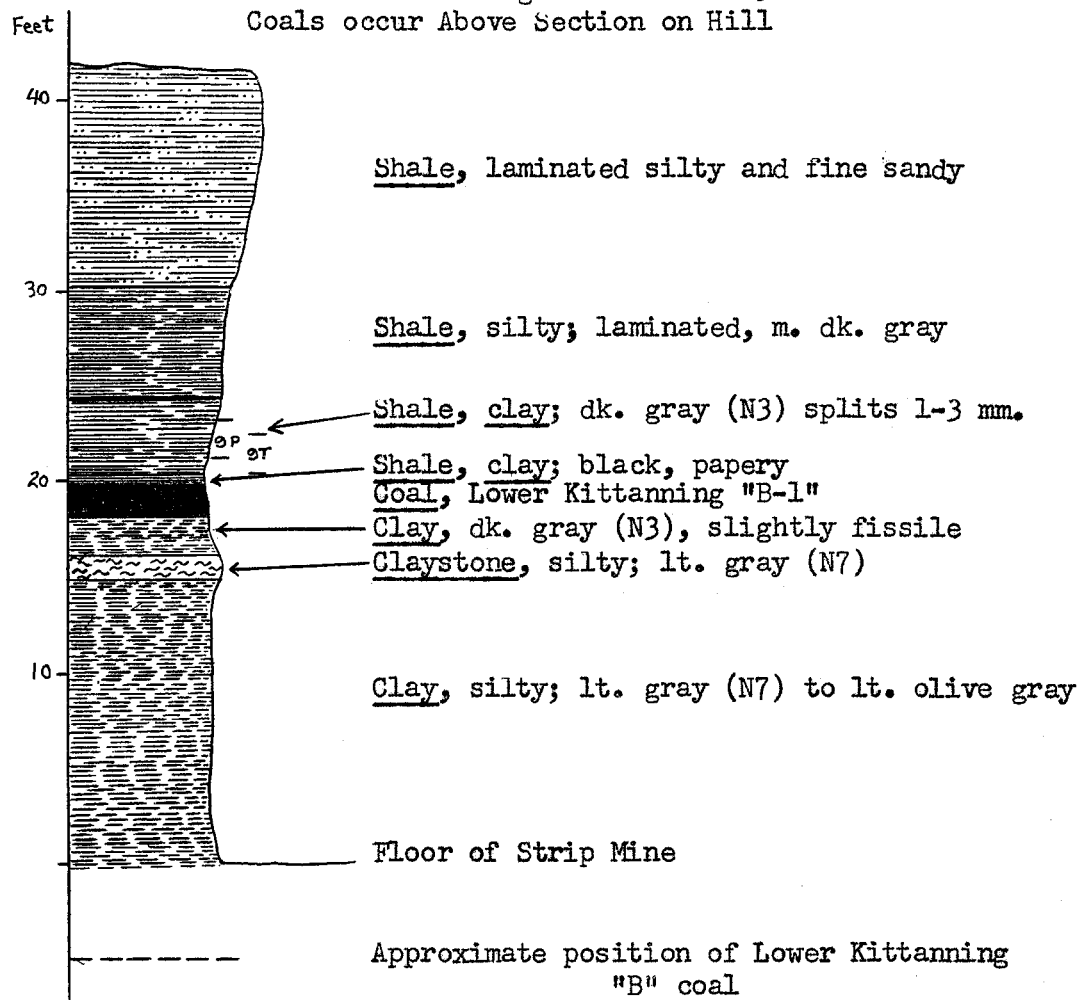
1. Additional cycles are added to the sequence between split coals.
2. The character of the interval between split coals may vary laterally over a few miles from clay, to a normal cycle, to a completely sandy sequence which interfingers laterally with normal cyclic deposits on both sides.

- 27.6 Strip mines in Brookville and Lower Kittanning coals to left of road.
- 29.4 Bear right at "Y". Town of West Decatur.
- 29.6 Turn left at junction with Route 322. Continue west on Route 322.
- 31.0 STOP 3 A: Park off pavement to right of road. Road cut exposes 6 to 8 feet of massive Pottsville sandstone, a quartzite showing some cross-bedding. Contrast the white color of this rock with the gray of the less clean sandstones at Stops 1, 2 and 3.
- 31.5-6 Road cuts to left and right of the road expose cross-bedded Pottsville sandstone.
- 31.7 Turn left - up slight rise on paved road leaving Route 322. Road sign points (in opposite direction) toward Wallacetown.

- 31.8 Bear left at "Y" on macadam road.
- 32.8 Turn right (toward Bigler) on first macadam road since leaving "Y" intersection. Route 970.
- 33.4 STOP 4: Park off pavement along right side of road facing north. Walk short distance into strip mine.

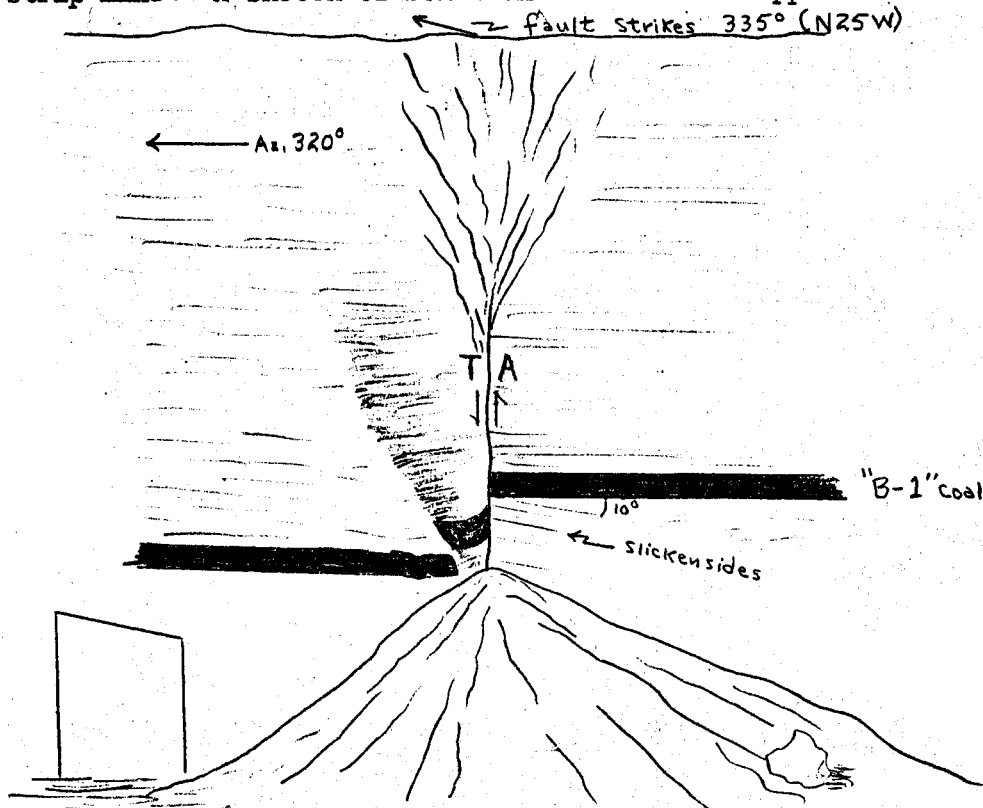
Features to be observed at this stop are a section of part of the Lower Kittanning coals and a small but typical high-angle fault showing a large component of strike-slip movement.

Lower Kittanning "B-2" and "B-3"  
Coals occur Above Section on Hill



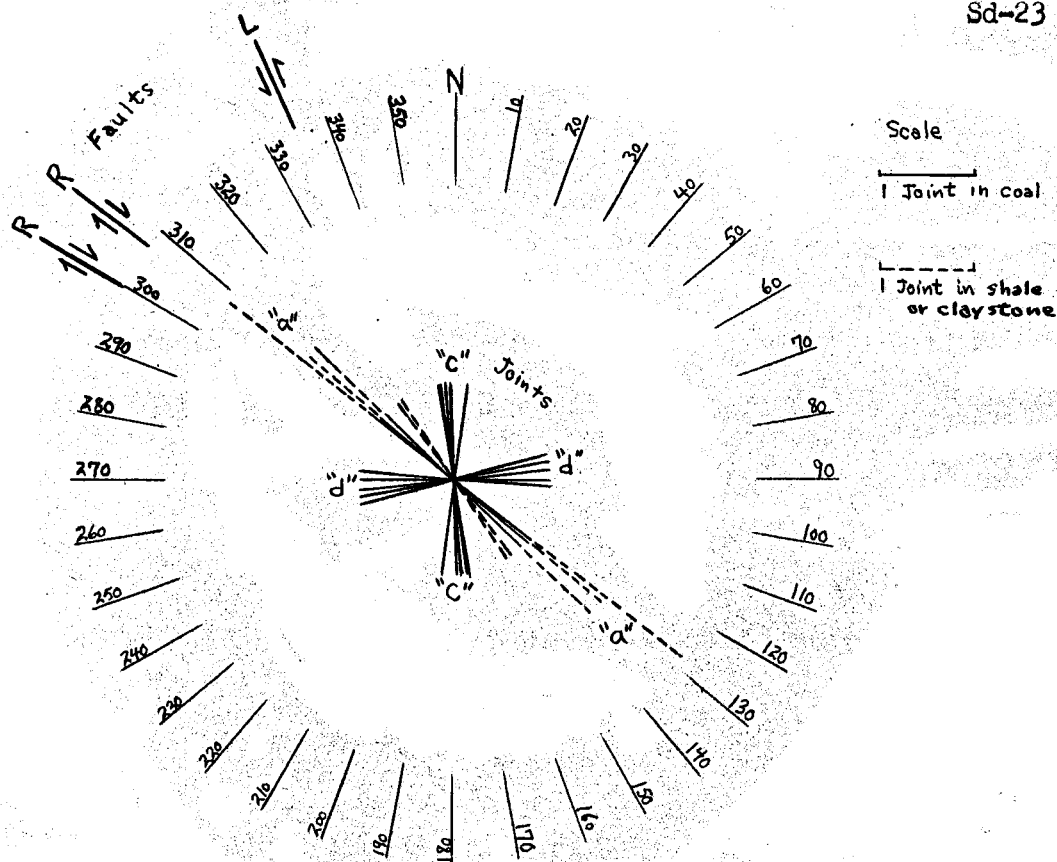
Only the Lower Kittanning "B-1" coal is exposed at this strip mine. The thick clay below the "B-1" coal is the same rock body seen between the "B" and "B-1" coals at Stop 3 and between the two "B" coal benches at Stop 2. The Lower Kittanning "B" coal is not exposed here but is known from drill cores to be 1 to 6 feet

beneath the floor of the strip mine. The "B-2" and "B-3" coals seen at Stop 3 are present on the hill in back of the strip mine. The clay between the "B" and "B-1" coals is mined extensively in this area and westward to Clearfield for use in the manufacture of yellow building brick. It is persistent enough to be used as a key bed in stratigraphic correlation. The best exposed fault is at the center of the strip mine. A sketch of relations at the fault appears below.



This fault strike N25W, dips nearly vertically, and displaces the "B-1" coal bed about 2 feet. A close inspection of the fault plane will show slickensides plunging approximately  $10^\circ$  on an azimuth of  $135^\circ$  (SE). Assuming that the slickensides indicate the direction of net slip the fault can be classified as a left-handed fault. (Left-handed fault - when looking along strike of the fault, block on left has moved toward observer; block on right has moved away from observer.) At the end of the strip mine nearest the road a complex network of high-angle faults is present all of which show slickensides plunging at small angles to the S.E. Faults striking N53W and N60W in this area show evidences of right-handed strike-slip movement.

Strike of joints in coal, shale and clay observed at the north end of the strip have been plotted on the following diagram together with fault strike orientations.



Joints of the "a" set (See INTRODUCTION) are present in the shale, clay and coal. Joints of the "c" and "d" sets are present in the coal. The strike of the "a" joint set falls between the strike of the right-handed and left-handed faults.

- 34.7 Bear left at Stop sign, following Route 970.
- 35.2 Turn right at Stop sign. Crossing railroad tracks.
- 35.4 Passing through Bigler, Pennsylvania.
- 35.7 Turn left at Stop sign. Intersection of Route 153 and Route 322. Continue toward Clearfield on Route 322.
- 36.1 Road cut exposing section of Lower Kittanning sands, shales and clays.
- 37.0 Road cut on right exposing Pottsville sandstone.
- 37.7 View ahead of strip mines in Lower, Middle and Upper Kittanning coals.
- 39.6 Road cut on right exposes Clarion sandstone.

- 40.6-.8 Road cut on right exposes cross-bedded Clarion sandstone.
- 42.6 Crossing Clearfield Creek.
- 42.8 Turn left off Route 322 on dirt road.
- 43.9 STOP 5: Park to right of road and walk .3 miles to section on the side of hill exposing Lower Kittanning to Lower Freeport coals. The stratigraphic section and detailed lithologic descriptions are given on following pages. The measurements were made approximately 100 yards N.E. of the mine entrance.

This section is one of the best exposures of the Allegheny formation in the area. The clay at the bottom of the section is approximately 200 feet below the Upper Freeport coal which crops out at the top of the hill.

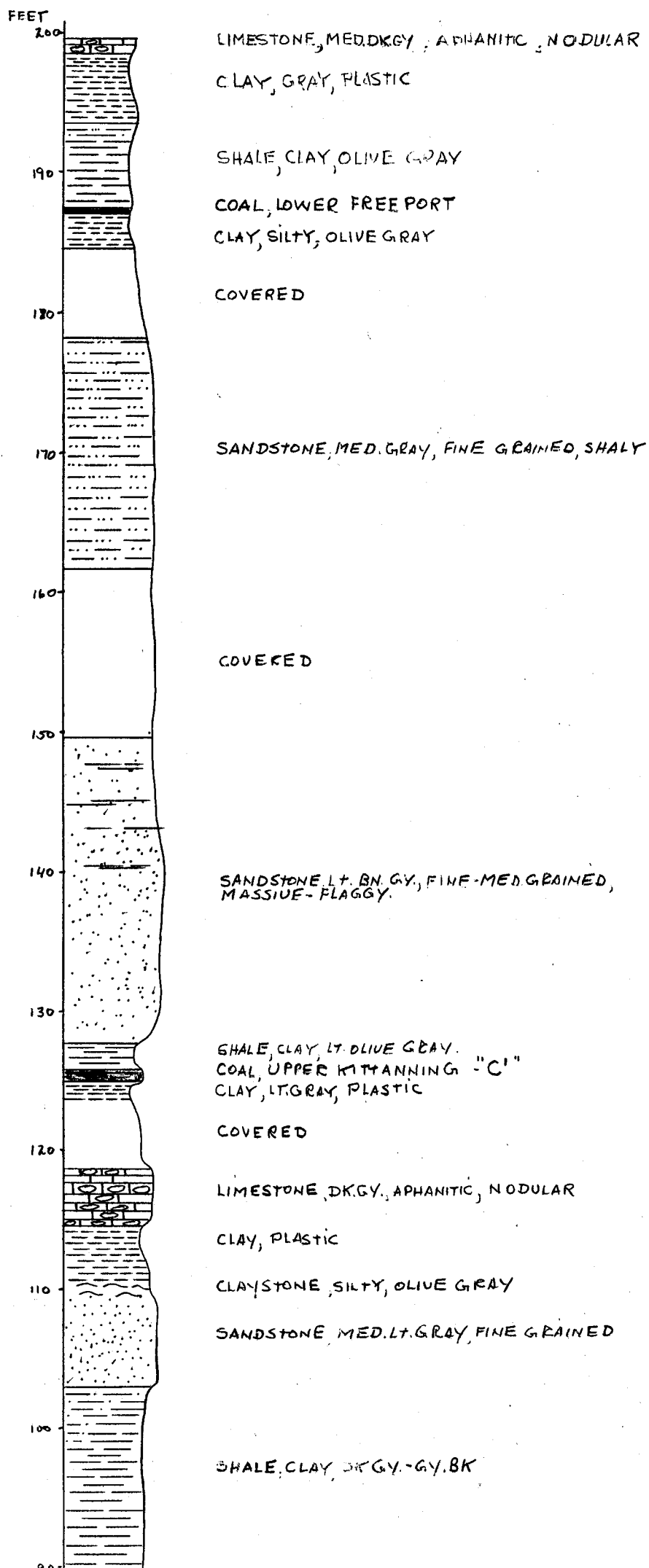
The lower part of the section illustrates one of the difficult problems in correlation in this area. The interval here is occupied by three coals and probably four. In adjacent sections the intervals and lithology between coals greatly changes (See Stops 2, 3 and 9). Fossil zones above the coals and the thickness and lithology of associated clays have been used in working out these relationships over a limited area.

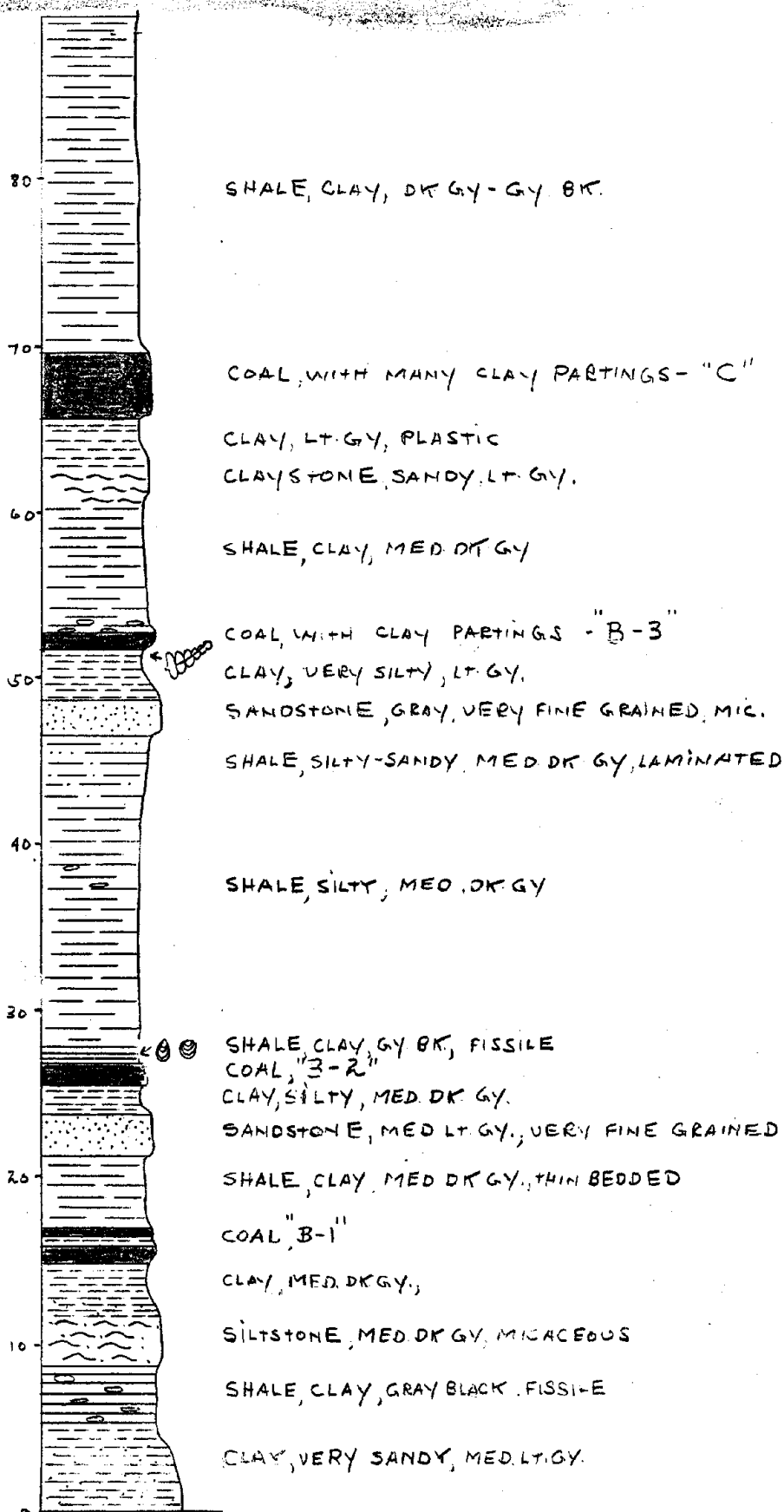
Two of the three limestones present in the Allegheny formation can be observed. These usually occur as dark gray or olive gray, aphanitic, nodular masses which weather a yellowish brown. They commonly occur in the clay beneath the coals and in places contain numerous coiled gastropods and some ostracodes. Although the limestones are quite lenticular, they are found over a wide area and hence are useful in correlation.

The thick sandstone above the Upper Kittanning coal is one of the major sand bodies in the Clearfield area. It should be contrasted with the one above the Middle Kittanning coal which shows even bedding and no evidence of channeling. The Lower Freeport coal is represented here by only a thin bone coal. One half mile to the southwest, it is three feet thick. (See Stop 6).

# Stratigraphic Section at Stop 5

Sd-25





Lithologic description of Stratigraphic  
Section at Stop 5

	<u>Feet</u>	
	<u>Thickness</u>	<u>Total</u>
<u>Limestone</u> , medium dark gray - olive gray, aphanitic in nodular masses 2"-2' long which weather light gray; scattered patches of resinous sparry carbonate occur throughout the rock -----	1.0	199.0
<u>Clay</u> , gray, plastic, with two thin coaly layers 10" and 2' from base -----	5.0	198.0
<u>Shale</u> , clay, olive gray, becoming sandy and laminated in upper few feet; some interbeds of 1-2" shaly sandstone occur in upper foot -----	6.0	193.0
<u>Coal</u> , bony - Lower Freeport "D" -----	0.5	187.0
<u>Clay</u> , olive gray, silty and blocky in lower part, be- coming more plastic toward top -----	2.5	186.5
Covered Interval -----	6.5	184.0
<u>Sandstone</u> , medium gray, very fine-grained, shaly, weathers greenish gray -----	16.5	177.5
Covered Interval -----	12.0	161.0
<u>Sandstone</u> , light brownish gray, fine to medium-grained micaceous and carbonaceous, massive in lower part flaggy in upper; some thin shale interbeds occur in upper part -----	22.0	149.0
<u>Shale</u> , clay, light olive gray with many plant fragments weathers light gray; upper contact concealed -----	1.2	127.0
<u>Coal</u> , bony, Upper Kittanning "C" -----	0.75	125.0
<u>Clay</u> , plastic, light gray -----	1.0	124.25
Covered Interval, probably clay -----	6.0	123.25
<u>Clay</u> , gray, plastic, with numerous limonite concretions	0.5	117.25
<u>Limestone</u> , dark gray, aphanitic, with patches of sparry carbonate 1-5 mm. in diameter; weathers into irregular, fluted nodules 6"-1' long, yellowish in color. A few small coiled gastropods present -----	2.4	116.75

	Thickness	Feet Total
Covered, float is claystone, olive gray, silty and micaceous -----	5.5	112.75
Sandstone, medium light gray, fine-grained, well sorted, micaceous on bedding planes, in regular beds 6"-1' thick. The lower contact is sharp, upper gradational, weathers light brownish gray --	6.0	107.25
Shale, clay, dark gray to gray black, fissile, grading upward into thicker bedded (1-2") more silty shale which weathers olive gray. Upper contact sharp -----	3.3	101.25
Coal, with many small clay partings, Middle Kittanning "C" -----	4.0	68.25
Clay, light gray, plastic -----	3.0	64.25
Claystone, sandy, light gray, weathering brownish -----	2.0	61.25
Shale, medium dark gray, clay to slightly silty, blocky, with no visible bedding: hollow, septate, limonite concretions, 4-5" long, 1-2" thick; often filled with fine silt or clay, occur in lower one foot -----	6.8	59.25
Shale, clay, black, with thin interbedded coaly layers represent a coal horizon - "B-3" -----	0.5	51.25
Clay, light gray, very silty with many root impressions -----	2.5	50.75
Sandstone, gray very fine-grained, micaceous, in beds 1-4" thick; grading upward into siltstone, weathers brownish -----	2.5	48.25
Shale, sandy-silty, medium dark gray to medium light gray, in finely laminated beds, 1-2" thick, with interbedded non-laminated shale: weathers rusty brown. Scattered ironstone concretions present in lower few feet -----	10.0	45.75
Shale, silty, medium dark gray, breaking into plates 1/8 - 1/4" thick: becomes more silty toward top --	9.0	35.75
Shale, clay, gray black, fissile, with lingulas of several species, upper contact sharp -----	1.25	26.75

	Thickness	Feet Total
<u>coal</u> , bony	0.25	25.5
<u>Coal</u> , with parting - "B-2"	0.75	25.25
<u>Clay</u> , silty, medium dark gray, with numerous carbonized root impressions which cut bedding; ironstone concretions occur in a 6" zone at base; unit becomes darker and less silty toward top	1.75	24.5
<u>Sandstone</u> , medium light gray, very fine-grained, slightly micaceous; lower foot resistant. Lower contact sharp, upper is gradational	2.75	22.75
<u>Shale</u> , clay medium dark gray, thin-bedded, weathering light gray and becoming more silty in upper part -	4.25	20.0
<u>Coal</u> , with partings - "B-1"	0.25	15.75
<u>Shale</u> , clay, dark gray	1.0	15.5
<u>Coal</u> , with 2-3" bony coal at base - "B-1"	1.5	14.5
<u>Clay</u> , silty in lower part, medium dark gray, with many root impressions; weathers into small light gray blocks. A zone of slightly limy concretions 3-4" in diameter occurs at base	2.5	13.0
<u>Siltstone</u> , medium dark gray, micaceous, resistant in lower one foot, grading upward into silty claystone; weathers light gray; the lower contact is sharp	3.0	10.5
<u>Shale</u> , clay, gray black, fissile, with scattered flat ironstone concretions, grading upward into medium dark gray, fissile, shale. Upper and lower contacts are sharp	3.5	7.5
<u>Clay</u> , very silty or sandy, medium light gray, hard and blocky, finely micaceous, becoming less silty and softer toward top; weathers grayish olive	4.0	4.0
Lower strip-"B" is probably present 6-10 feet below fill.		
Total thickness of section		199.0 feet

45.7 Turn left at "T" road intersection.

45.9 STOP 6: Park cars on right side of road. Walk southeast on dirt road into strip mine.

This section is typical of the Freeport cycles over much of the southern part of the Clearfield basin. The thin-bedded sandstone and sandy shale above the "D", the nodular limestone and calcareous clay between the coals and the black, platy shale with well preserved leaf impressions are distinctive features of these cycles. Not seen here, but present in many adjacent areas, is a split coal which appears from 7-10 feet above the "D" coal and beneath the limestone. Actually the thin bone coal above the lower sandstone in this section may occupy the position of the split.

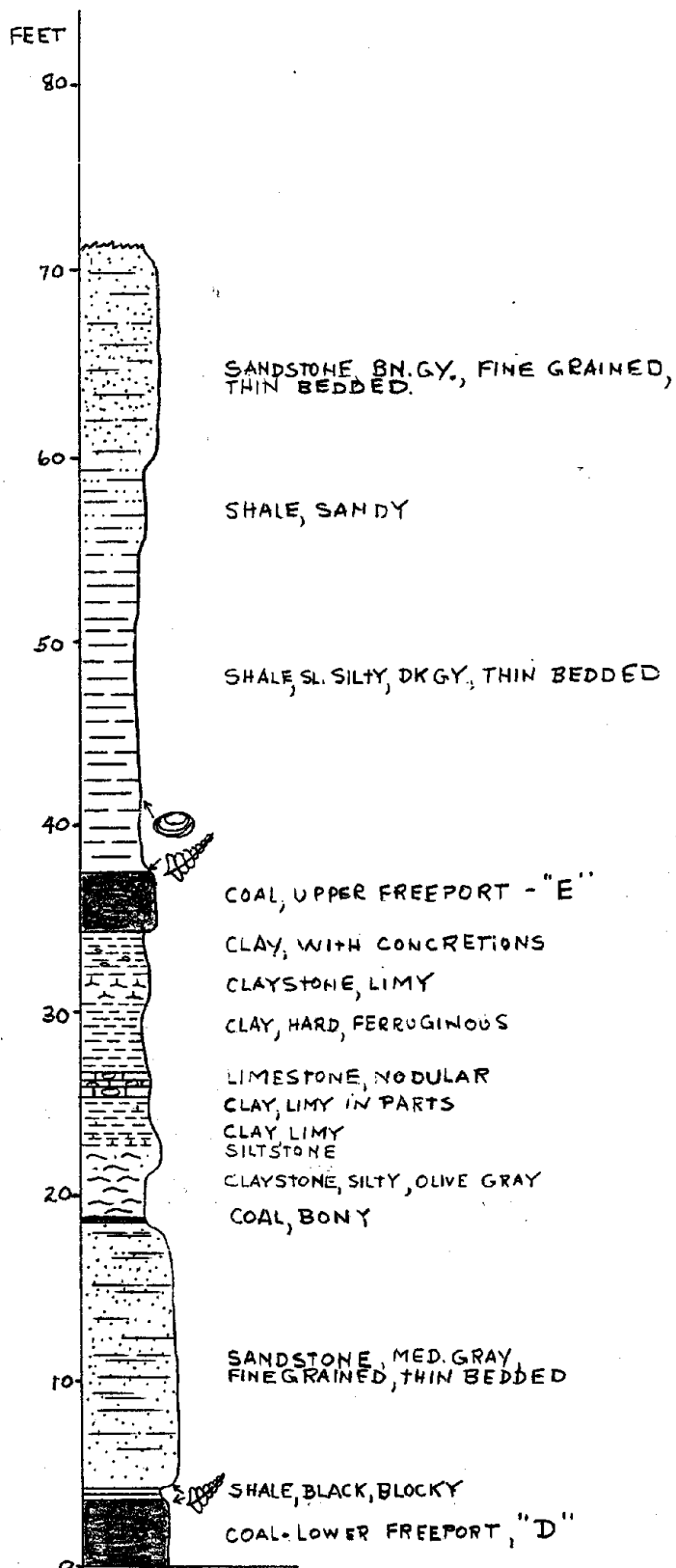
The interval between the "D" and "E" coals ranges from 15-60', averages 35-40'. One of the most striking changes in interval is between sections 5 and 6 (see correlation chart). The "D" coal is 2.5 - 3' thick at most places, commonly with a thin clay parting several inches from the base.

Lithologic description of Stratigraphic  
Section at Stop 6

	<u>Thickness</u>	<u>Feet</u> <u>Total</u>
<u>Sandstone, brownish gray, fine-grained, in regular beds 1-3" thick, with interbedded shaly sandstone</u>	10.0	71.75
<u>Shale, slightly silty, dark gray, in faintly laminated 1/8 - 1/16" beds, with well preserved leaf impressions in lower part. Several poorly preserved pelyceps(?) noted; unit grades upward to very silty shale</u>	22.0	61.75
<u>Coal, clean, bright - Upper Freeport "E"</u>	3.25	39.75
<u>Clay, silty, light gray with limonite concretions</u>	2.0	36.5
<u>Clay, silty, dark gray</u>	2.5	34.5
<u>Claystone, medium dark gray, ferruginous, with irregular bedding</u>	1.0	32.0

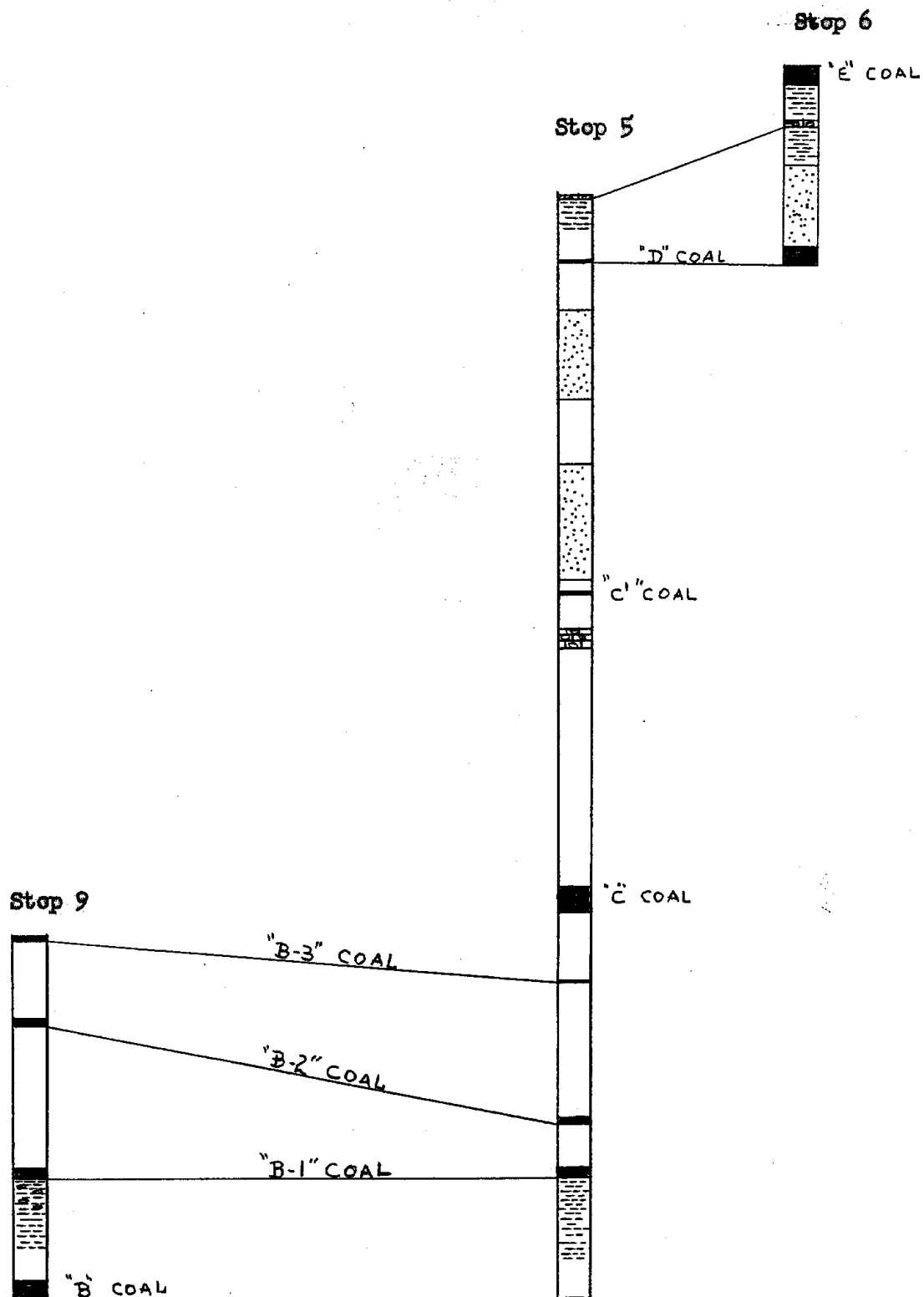
	<u>Thickness</u>	<u>Feet</u> <u>Total</u>
<u>Clay</u> , silty, dark gray, weathering to small irregular fragments	2.0	31.00
<u>Clay</u> , hard, very ferruginous	0.25	29.0
<u>Clay</u> , plastic, yellow brown	1.00	28.75
<u>Limestone</u> , dark gray, aphanitic, freely effervescent in HCL, weathering into nodular, yellow brown masses, averaging 1' in length. Some small gastropods present	0.15	27.75
<u>Clay</u> , medium dark gray, with numerous nodules or irregular masses of limy clay coated with iron oxide	2.0	26.25
<u>Clay</u> , olive brown, hard, very limy, freely effervescent in HCL; weathers greenish gray	0.75	24.25
<u>Claystone</u> , silty, olive gray, with a one foot bed of resistant, medium gray, very silty claystone or siltstone at top; unit weathers light olive brown	2.25	23.50
<u>Claystone</u> , slightly silty, olive gray, somewhat softer than unit above; no bedding visible	1.25	21.25
<u>Shale</u> , clay, dark gray	0.25	20.00
<u>Coal</u> , bony, soft	$\frac{1}{2}$ "	
<u>Sandstone</u> , medium gray, fine-grained, very micaceous, in beds 2-1" with thin clay or sandy shale interbeds $\frac{1}{4}$ - 2" thick; sandstone weathers rusty brown	14.0	19.75
<u>Shale</u> , clay, dark gray, platy with plant impressions; grades upward to medium gray sandy shale in 1-2" beds	0.2	5.75
<u>Shale</u> , black, hard and brittle, very carbonaceous, weathers to rectangular blocks	0.25	3.75
<u>Coal</u> , with 2" clay parting 13" from base - "D"	3.5	3.5
Total thickness of section		71.75

## Stratigraphic Section at Stop 6



Correlation Chart

Horizontal Scale: 1" =  $\frac{1}{4}$  mile  
Vertical Scale: 1" = 30 feet



- 46.0     Turn right at "T" intersection with macadam road.
- 46.3     Turn right at Stop Sign at road intersection. View north toward  
Susquehanna River valley and Clearfield, Pa.
- 46.9     Entering Clearfield.
- 47.4     Turn right at Stop Sign . "T" intersection with Route 322  
Susquehanna River, west branch.
- 47.5     Bear left at "Y" on road paralleling river.
- 47.8     Straight ahead at Stop Light . School on left.
- 48.1     Turn left at Stop Light . Cross west branch Susquehanna River  
on bridge.
- 48.2     Turn right on Route 879 at far end of bridge. Continue on Route 879.
- 50.3     Turn right on dirt road just beyond sharp left bend in Route 879.  
Amoco gas station on corner.
- 50.4     STOP 7? Road cut exposing cross-bedding in the Clarion sandstone.

This exposure clearly illustrates the type of cross-bedding found in Pennsylvania sandstones of the area. A sketch of part of the outcrop appears on the accompanying page.

Terminology slightly modified from McKee and Weir(1953) is used in descriptive labels on the sketch. A cross-bed (cross-stratum of McKee and Weir) is a single layer deposited at an angle to the original dip of the formation. A set of cross-beds is a group of conformable beds deposited with initial dip and separated from other sets by surfaces of erosion or non-deposition.

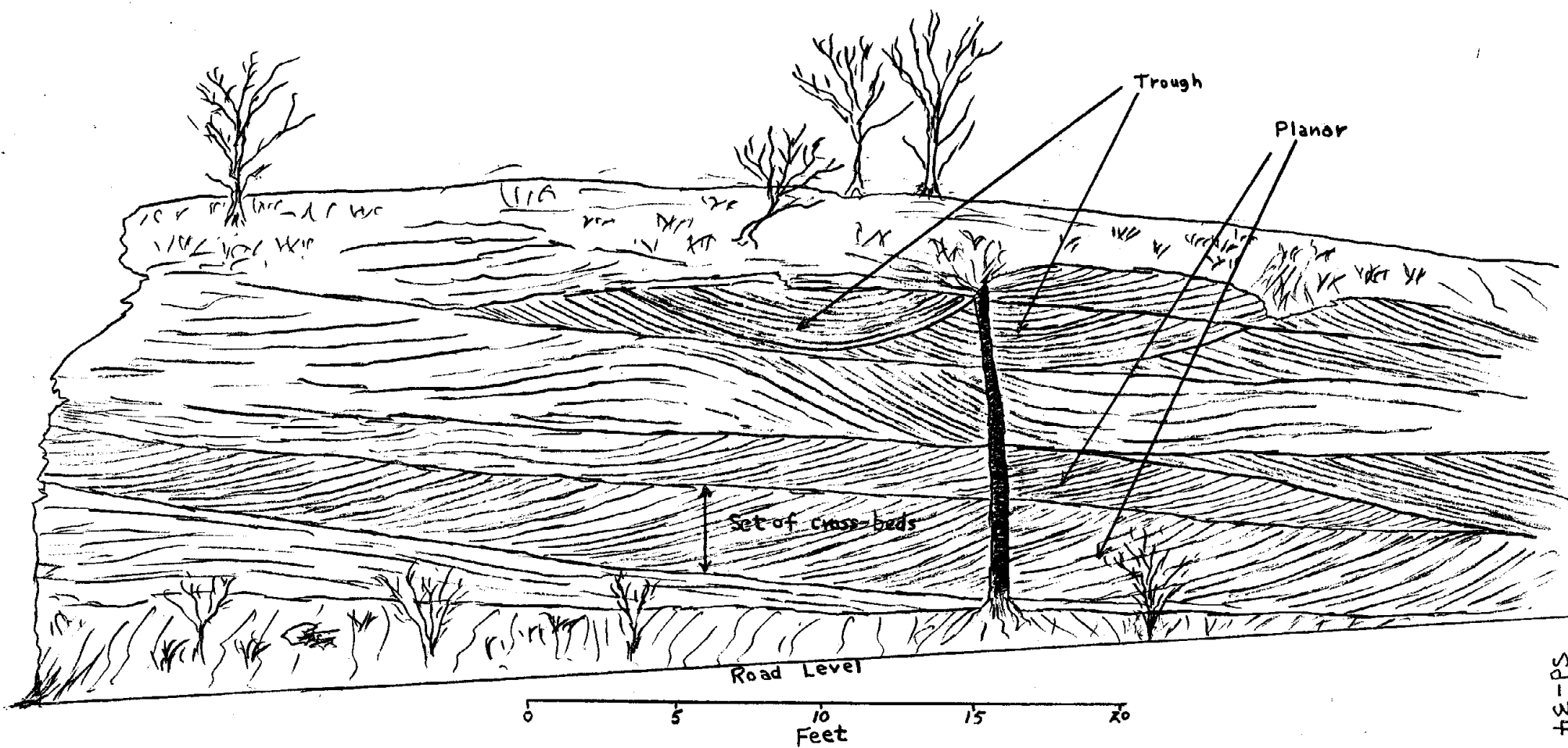
McKee and Weir(1953,p.387) classify cross-bedding(cross stratification) on the basis of the character of the lower boundary surface of the set of cross-beds.

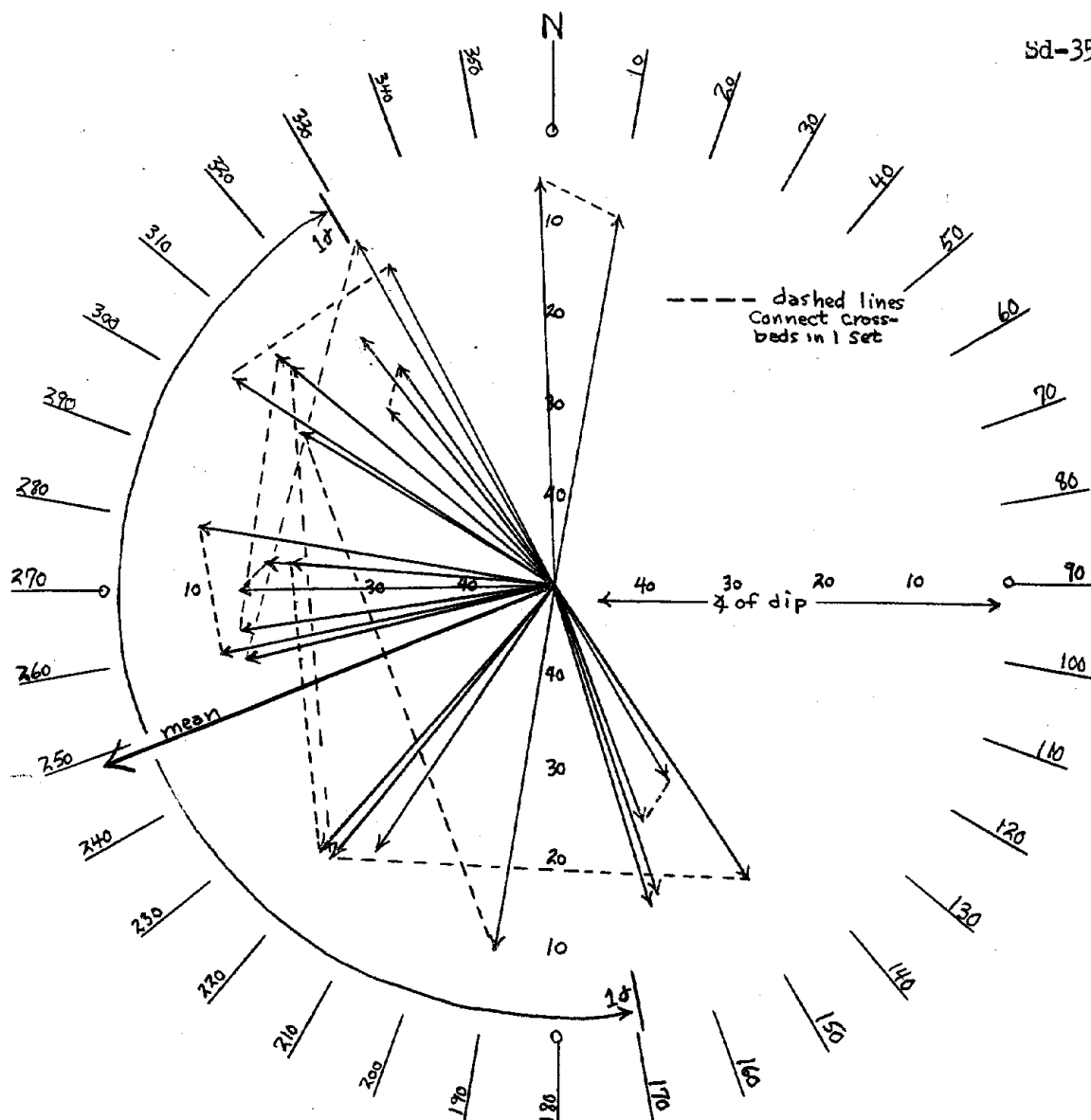
1. Simple cross-stratification - the lower bounding surface of sets are nonerosional surfaces.
2. Planar cross-stratification - the lower bounding surfaces of sets are planar surfaces of erosion.
3. Trough cross-stratification - the lower bounding surfaces of sets are curved surfaces of erosion.

As indicated on the sketch, both planar and trough cross-stratification is present in the outcrop.

Sketch of Cross-bedding at Stop 7

← Az. 318°





The above diagram shows dip directions of 27 cross-beds. Arrows indicate direction and amount of dip of cross-beds. Where possible two observations were made on each set of cross-beds.

Although a cursory inspection of the outcrop seems to indicate no preferred dip direction of cross-beds this plot shows most dip directions to be in the northwest and southwest quadrants.

The average dip direction of cross-bedding is azimuth  $249^{\circ}$  (S  $69^{\circ}$  W). The mean and variation about the mean are plotted on the diagram. Current flow is inferred to have been toward the observer.

50.7 STOP 8: The stratigraphic section for Stop 9 and the Correlation Diagram show the position of the coals at this stop.

This section shows a good example of coal splitting. The upper coal rapidly rises into the highwall, so that in a distance of approximately

100 feet, a complete cycle 20-25' thick separates the two coals. The split coal is correlated with the "B-2" coal at Stop 5, where an interval of only 10 feet separates it from the "B-1". Such rapid changes in interval seem to be characteristic of the Lower Kittanning coals. Maximum interval between split coals is commonly attained within a single strip mine in a lateral distance comparable to that seen at Stop 8. Evidence from the Lower Kittanning coals in the Philipsburg-Houtzdale area indicates that after the interval between split coals is attained, it remains fairly constant over areas of 15 or 20 square miles (dimensions approximately 10 miles north-south and two miles (minimum) east-west. (See Fence Diagram).

In contrast, the split intervals found in the Middle Kittanning and Upper Kittanning coals in both the Philipsburg and Clearfield basins are extremely irregular.

51.1 STOP 9: The stratigraphic section and lithologic descriptions are given on the following pages. The section is composite, having been measured at opposite ends of the hill.

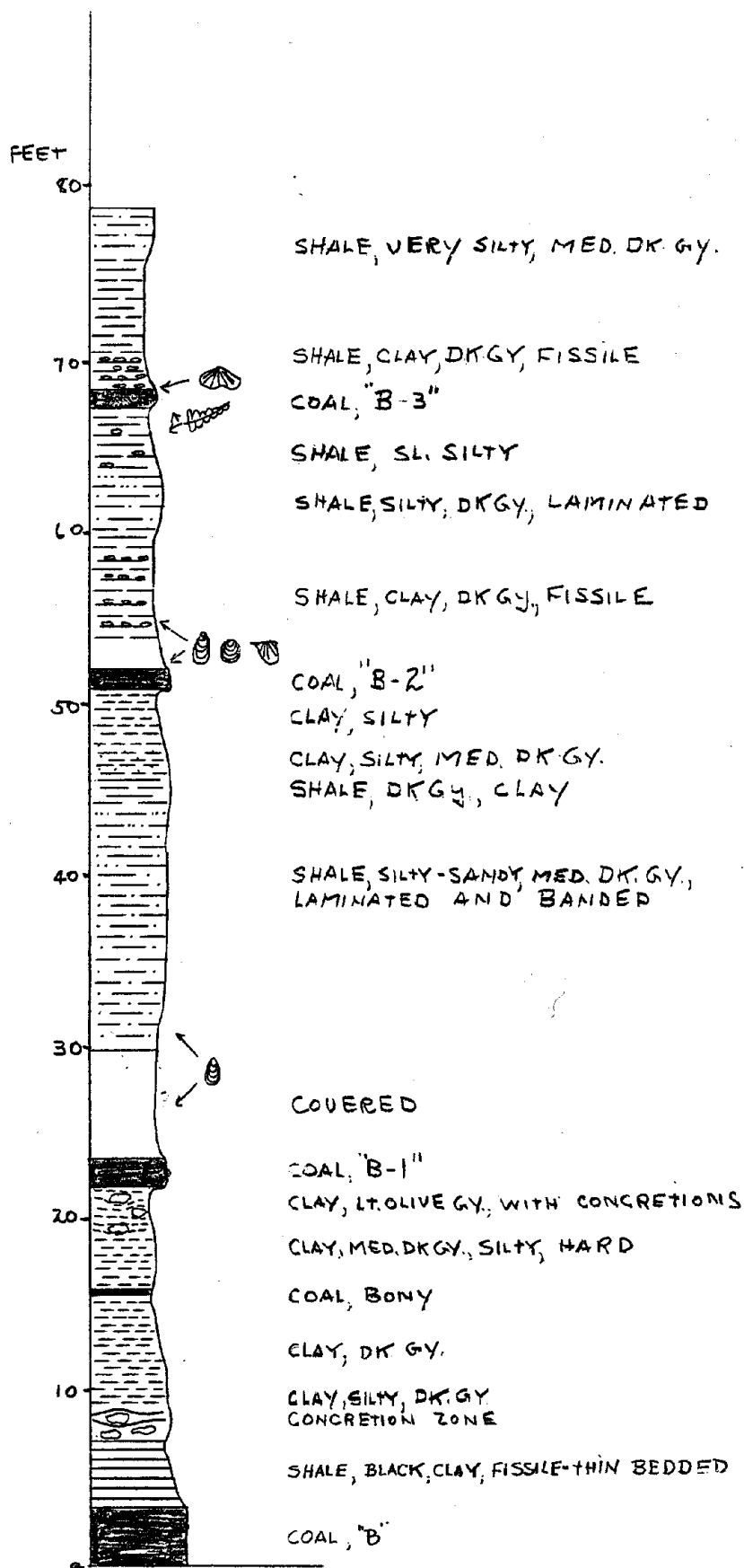
The lithology of the clay and concretions beneath the "B-1" coal is well illustrated here. Large concretions of this type are believed to occur only at this stratigraphic position. In some localities, they coalesce to form a single, thick concretionary bed. A chemical analysis of one of these gave the following results:

loss on ignition	- 24.9%
acid insolubles	- 19.2%
R <sub>2</sub> O <sub>3</sub>	- 51.5%

These concretions are believed to occupy the same position as those beneath the "B-1" coal at Stop 5, where they were observed in front of the mine entrance.

Fossils occur above the upper three coals (see stratigraphic section). A rather unusual zone of pyritized brachiopods is present above the "B-3" coal. This zone has been traced to Stop 8, but has not been found elsewhere. It seems to be characteristic that the marine fossil zones are not persistent, while the lingula zones are strikingly so. In almost every area, where normal cycles are developed, lingulas can be found above the Lower Kittanning coals. So far, lingulas have not been found in abundance above coals higher than the "B-3" coal.

## Stratigraphic Section at Stop 9



Lithologic Description of  
Stratigraphic Section at Stop 9

<u>Shale</u> , very silty, medium dark gray, finely micaceous and carbonaceous, no observable bedding in lower 2 feet, becoming more even bedded toward top. Rock weathers into irregular fragments $\frac{1}{4}$ - $\frac{1}{2}$ " thick, olive gray or gray in color - - - - -	3.0	78.00
<u>Shale</u> , clay, dark gray, thin bedded, with a few scattered small concretions in lower 1 foot; weathers into small chips, brownish in color - - - - -	4.5	75.00
<u>Shale</u> , clay, dark gray, fissile, with numerous bedded nodular concretions, $\frac{1}{2}$ -2" thick; 4-6" apart, which form 10-15% of unit - - - - -	2.5'	70.50
<u>Shale</u> , clay, black, soft, fissile, pyritiferous, with many small irregular pyrite nodules and pyritized brachiopods - - - - -	0.5'	68.0
<u>Coal</u> , dirty with many thin clay partings and a 5" bony zone at top -	1.25	67.50
<u>Shale</u> , clay, dark gray, thin bedded, with a profusion of plant impressions - - - - -	1.0	66.25
<u>Shale</u> , slightly silty, dark gray, non laminated, splits with irregular fracture, weathers brownish. A few scattered ironstone concretions present. - - - - -	3.0	65.25
<u>Shale</u> , silty to sandy, dark gray, finely laminated, in 1-3" beds, weathering brownish and into thin plates 1/16" thick - - - - -	3.0	62.25
<u>Shale</u> , clay, dark gray, fissile, thin bedded, with $\frac{1}{2}$ -1" bedded reddish brown ironstone concretions, 6-8" apart, weathers brownish -	6.25'	59.25
Covered - - - - -	2.00	53.00
<u>Coal</u> bony - "B-3" coal - - - - -	1.0'	51.0
<u>Clay</u> , silty, medium dark gray, black, hard, with many root traces, weathers light gray - - - - -	3.5'	50.0
<u>Clay</u> , very sandy, medium dark gray, blocky, hard, with many sandy lenses or nodules in lower part; weathers light gray and rusty brown. Iron oxide layers occur throughout mass; many root traces present - - - - -	1.5	46.5
<u>Shale</u> , slightly silty, dark gray, thin bedded, grading upward to clay - - - - -	2.0	45.0

<u>Shale</u> , very silty to sandy, medium dark gray to dark gray, strongly color banded on weathered surface; light olive gray bands, $\frac{1}{4}$ - $\frac{1}{2}$ " thick, consist of finely laminated sandy shale; darker bands, somewhat thicker, are silty. Fine mica and carbonaceous matter are abundant on bedding planes. A few lingulas occur in lower part in the silty layers - - - - -	10.0	43.00
<u>Shale</u> , slightly silty, gray black, thin bedded (1/18-1/16"), breaking into smooth, flat, fragments and weathering light greenish gray. Some parts appear to be faintly banded. Numerous lingulas occur in thin zones throughout unit - - - -	4.0	33.00
Covered interval to base of strip mine where "B-1" is covered by fill - - - - -	6.0'	29.00
Section continued $\frac{1}{4}$ mile north		
<u>Shale</u> , black, fissile, very coaly, sulphurous, weathering greenish black. In a distance of 100 yards, the shale passes into a mineable coal - - - - -	1.5'	23.00
<u>Clay</u> , light olive gray, slightly silty, soft, with a resistant, silty ferruginous zone, 4" thick at base, weathers light gray. Numerous, oval, medium dark gray, slightly limy, siderite-siltstone concretions, 6"-2' long, 6"-1' thick, occur throughout but predominate at base - - - - -	3.0	21.50
<u>Clay</u> , silty - sandy, dark gray to gray black, hard and blocky, micaceous and carbonaceous - - - - -	1.75'	18.50
<u>Clay</u> , plastic; dark gray to gray black, flaky, soft - - - - -	1.0	16.75
<u>Coal</u> , bony - - - - -	2"	
<u>Clay</u> , very silty, medium dark gray, hard, blocky, with root impressions throughout - - - - -	1.0	15.75
<u>Clay</u> , light olive gray, plastic; weathering light gray and stained with iron oxide - - - - -	2.0	14.75
<u>Clay</u> , very slightly silty, dark gray to gray black, semi-plastic, becoming lighter in color toward top. A 6" zone of very silty, ferruginous, hard, lumpy clay occurs at base - - - -	3.5	12.75
<u>Shale</u> , clay, gray black, thin bedded (1/8-1/16"), grading upward into clay. Large, oval, hard, dense, slightly limy, ironstone nodules (1.5'-6" long, 2-4" thick) occur throughout unit and comprise 15-20% of it - - - - -	2.25	9.25

<u>Shale</u> , clay, gray black, fissile, weathering greenish gray - - - -	3.0'	7.00
<u>Shale</u> , gray black, hard, brittle, breaking into rectangular blocks - - - - -	0.75'	4.00
<u>Coal</u> , with many clay partings, "B" - - - - -	3.25'	3.25
Total thickness of section - - - - -		76.00'

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