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TWELFTH ANNUAL FIELD CONFERENCE

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FROM THE CAMBRIAN TO THE SILURIAN

NEAR STATE COLLEGE AND TYRONE

By

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(with G. M. Kay and F. M. Swartz)

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FROM THE CAMBRIAN TO THE SILURIAN

By Paul D. Krynine

STRATIGRAPHY AND PETROGRAPHY

The lower Paleozoic section, well exposed near State College, extends from the middle Cambrian to the lower Silurian and consists of limestones and sandstones of the orthoquartzitic and graywacke classes. The total thickness reaches 11,200 feet.

CAMBRIAN

WARRIOR LIMESTONE: "The Warrior limestone, named by Butts from Warriorsmark Creek, a few miles southwest of the Bellefonte quadrangle, ranges in character from a thick-bedded blue, comparatively pure limestone and dolomite to a thin-bedded shaly and sandy rock. It contains several oolitic beds, commonly fossiliferous, and beds of edgewise conglomerate composed of many thin lenses of limestone irregularly distributed in a limestone matrix." (Butts and Moore, p. 13)

A petrographic study of the Warrior limestone at Locality 5 showed that it carries a considerable amount of volcanic ash which is distributed at least through 200 feet of the Warrior and possibly more. The insoluble residue which forms 2.7% of the rock carries a large amount of the hexagonal biotite flakes (partly altered to chlorite), good apatite crystals and apparently a hypersthene-like (?) mineral. There are no well-defined bentonites in the Warrior and the volcanic material is hidden throughout the limestone. Numerous Cryptozoon layers are present. The sedimentation is cyclic and a fairly typical cycle may consist of the following units:

Cryptozoon	1-2 feet
Massive black limestone (possibly part of the Cryptozoon reef)	1-2 feet
Thin-bedded limestone	3-5 feet

GATESBURG FORMATION: The Gatesburg formation, which ranges in thickness from 1600 to 1750 feet, consists of a series of alternating cycles made of beds of massive black dolomite, platy buff dolomite, and quartzitic sandstone. In the southern portion of the Gatesburg there is a thin-bedded limestone about 100 feet thick, named the Ore Hill member which contains a suite of trilobites. The Gatesburg can be correlated paleontologically with the Franconia formation and with the Conococheague limestone, and on the basis of heavy minerals with the Potsdam quartzites of New York State. The best exposure of the Gatesburg is at Locality 7 between Tyrone and Birmingham and a poorer section is at Locality 4 on Route 322.

Five fundamental rock types can be differentiated in the field within the Gatesburg formation:

1. Buff to gray, dense to very finely crystalline dolomite, associated with fine to medium sand and sometimes containing large oolites.

2. Medium to coarse sandstone, frequently conglomeratic with fragments of buff dolomite. The sandstones seen in the Birmingham outcrop are calcareous, but at Sand Ridge and near State College quartzitic sandstones were also observed. Occasionally black oolitic chert nodules are present.

3. Thin-bedded black to dark reddish-brown dolomite, very finely to finely crystalline. Shows bedding caused by layers of silt or fine sand.

4-A. Massive black dolomite, finely to medium crystalline, grading upwards into

4-B. Massive black dolomite in which black oolites can be identified

Black oolitic chert nodules common at upper and lower contacts.

5. Cryptozoon and other algal beds.

An ideal, complete lower Gatesburg cycle may be visualized as follows:

5. Cryptozoon bed . . . . . 3"

4-B. Massive black dolomite with oolites, grading downward into . . . . . 1' to 3'
4-A. Massive black dolomite

3. Thin-bedded black dolomite . . . . . 4' to 8'

2. Missing

1. Buff dolomite, silty, with a few coarse sand grains, interbedded with thin-bedded black dolomite . . . . . 3" to 2'

Two main types of Middle Gatesburg cycles can be identified:

Type A

5. Cryptozoon bed . . . . . 5"

4-B. Massive black dolomite with oolites, grading downward into . . . . . 1' to 6'
4-A. Massive black dolomite

3. Missing

2. Sandstone, often conglomerate . . . . . 1' to 10'

1. Buff dolomite, lenticular at base of sand . . . . . 2" to 1'

Type B

5. Missing

4-B.
4-A. Missing

3. Thin-bedded black dolomite, sometimes highly silty . . . . . 1' to 14'

2. Sandstone, conglomeratic . . . . . 3" to 10'

1. Buff to gray dolomite . . . . . 3" to 6'

The Upper-Middle portion of the Gatesburg formation contains approximately 130 feet of massive black to dark gray dolomite, possibly correlatable with the Ore Hill limestone member farther south.

A typical Upper Gatesburg cycle can be reconstructed as follows:

5. Missing

4-B. Usually not identifiable
4-A. Massive black dolomite . . . . . 1' to 8'

3. Usually not identifiable

2. Sandstone, conglomeratic . . . . . 3" to 12'

1. Buff dolomite, distinctly interbedded with silt and fine sand . . . . . 3" to 11'

Petrographically, rocks of the Gatesburg are composed of two types of constituents: clastic particles and chemically or organic precipitates. The major constituents are clastic detrital silicates (quartz and some microcline), clastic carbonates and chemically precipitated carbonates. A somewhat less important, though a very conspicuous constituent is chemically precipitated silica, either chert or secondary quartz. The heavy minerals are extremely monotonous and consist mostly of tourmaline and zircon. These minerals are well rounded and the tourmaline can be divided into thirteen different types which occur always in the same percentages. These varieties, based on six basic colors and the character of inclusions, are as follows:

Type I	Colorless tourmaline, containing inclusions . . .	1%
Type II	Colorless tourmaline, without inclusions	7%
Type III	Colorless tourmaline, with an extremely faint yellowish pleochroism	4%

Type IV Black, non pleochroic tourmaline, opaque, but gives good interference figures 13%

Type V Brown tourmaline with rutile inclusions . . . . . traces

Type VI Brown tourmaline of a typical GOLDEN ORANGE brown shade, which cannot be confused with any other shade of brown 14%

Type VII Brown tourmaline with few inclusions 35%

Type VIII Brown tourmaline with many inclusions. In practice there are almost no transitional gradations between Types VII and VIII 2%

Type IX Green tourmaline with few inclusions, easily differentiated from: 19%

Type X Green tourmaline with many inclusions . . . . . traces

Type XI Blue tourmaline, pleochroic in shades of mauve to blue 4%

Type XII Blue tourmaline, weakly or non pleochroic in pale blue 1%

Type XIII Varicolored tourmaline ("watermelon" variety) showing several colors in one grain, the most common one being half blue, half yellow . . . . . traces

A recapitulation of the Gatesburg shows that it is characterized by the following sedimentary criteria:

(1) The mineral composition of the silicates - the high amount of quartz, all of igneous derivation; an average ratio of quartz to feldspar of 80 to 20; a notable scarcity of micas outside of certain subordinate horizons; a low content of heavy minerals with a notable predominance of tourmaline and zircon; and a scarcity of all other minerals except garnet, which occurs in the same layers as the micas.

(2) The high ratio of carbonates to silicates (70 to 30), with a predominance of dolomite and dolomite-ankerite among the carbonates.

(3) The mixture of carbonates and silicates in all proportions to form four fundamental rock types which can be classified on the basis of composition, texture, stratification, and color.

(4) The repetition of these rock types over and over to form a series of sedimentary cycles. (Fifty-three cycles were observed near Tyrone in 500 feet of well-exposed strata. Observations on other outcrops of the area show such a cyclical development to be universal throughout the Gatesburg formation.)

Since 30% of the Gatesburg consists of relatively insoluble silicates which as a rule are cemented to a large extent by soluble carbonates, it follows that upon weathering and leaching, very deep sand soils develop. These soils in many cases reach a thickness of 30 to 60 feet and may consist of perfectly loose, porous, unconsolidated white sands. The possibility that similar zones of weathering may have formed during Middle Ordovician time on top of the exposed Gatesburg and may have acted upon burial as fluid reservoirs is discussed in the text under "Bellefonte sandstone."

The Gatesburg sandy fraction contains up to 10 or even 20% of microcline, generally with secondary overgrowth which upon long exposure of the Gatesburg may decay and form a white kaolin.

Reworked, transported kaolin deposits (highly mixed with fine-grained quartz and chalcedony) occur at many placed in the Gatesburg. They probably stem from the flushing and redeposition in small basins of this secondary kaolin formed from the K-feldspars within the Gatesburg.

The Gatesburg has suffered considerable chemical weathering during late Tertiary time and this weathering has resulted in addition to the formation of the clay, also in the development of secondary manganese and hematite - limonite ores (after ankerite ?). The best-known example of these secondary iron ores is the Scotia iron deposit. The Scotia mine operated between 1890 and 1920 and an attempt was made to revive it during the war in 1944.

MINES DOLOMITE MEMBER OF THE GATESBURG: The Mines dolomite really should be considered as an upper member of the Gatesburg. It consists predominately of coarse-grained, light to very dark gray dolomite, at places highly bituminous. There is a very large amount of chert which occurs either as early syngenetic oolites, contemporaneous with deposition or as early diagenetic (late syngenetic) secondary chalcedony replacing cryptozoa. The siliceous oolite layers may reach 15 to 20 inches in thickness.

Siliceous oolites are abundant in the Upper Cambrian Gatesburg and Mines formations of Central Pennsylvania. They recur cyclically in 1- to 15-inch layers interbedded with calcareous oolites, quartzose sandstones, quartzites, dolomites, limestones, and local intraformational conglomerates.

Typical oolites are developed in perfect concentric (radial!) rings around variable cores, generally quartz grains. The primary character is evident from crushing and rehealing and from the occurrence of broken siliceous oolites as detrital fragments in intraformational conglomerates directly above the oolitic layers.

Two pene-contemporaneous generations of silica are apparently present: (1) body of oolites, deposited concentrically during free rolling period, and (2) interstitial silica between oolites after movement. This second generation silica may differ in color from the main oolite body and forms festoons and other botryoidal excrescences protruding from the oolite.

Siliceous oolites and associated sandstones both in the Gatesburg and in the Mines show evidence of considerable seabottom chemical activity as expressed

in authigenesis of quartz, feldspars (both microcline and albite), tourmaline, anatase, rutile, and carbonates. Authigenic tourmaline is a conspicuous feature of the Gatesburg and Mines formations.

There is no evidence of any important late secondary silicification of carbonates outside of the Cryptozoa; but on the contrary, large-scale local replacement of secondary silica by pene-contemporaneous dolomite is abundant. This dolomite is interpreted as the latest mineral of the syngenetic stage.

ORDOVICIAN SYSTEM

BEEKMANTOWN GROUP, STONEHENGE LIMESTONE: "The Stonehenge limestone consists chiefly of comparatively pure blue limestone, but there is some slightly magnesian limestone, and at one locality on Spring Creek a thick bed of coarse dark-bluish dolomite occurs. The limestone ranges from thin beds at the base to thick beds in the middle and upper portions. One characteristic feature of the formation is a reddish thin-bedded fossiliferous limestone conglomerate occurring at the base of the formation almost throughout the quadrangle. In places in the lower part of the formation calcareous shale containing rare specimens of a dictyonemoid graptolite occurs as partings between thin layers of limestone. Edgewise conglomerate is very common and of striking types, and near the top of the formation there is a persistent bed of oolitic limestone and red-spotted limestone conglomerate in which trilobites and gastropods are fairly plentiful. The purer limestone beds of the formation are commonly burned for farmers' lime." (Butts and Moore, p. 21)

NITTANY DOLOMITE: The Nittany dolomite reaches 1200 feet in thickness. It consists of dark crystalline (granular) dolomite, at many places brecciated and carrying a fair amount of oolites and some cryptzoon beds. This dolomite contains between 2 and 5% of insoluble materials which upon mineralogical study appears to be made mostly of the clay mineral beidellite. The Nittany dolomite contains many pores, cavities, and even very large caverns. The Penn State campus is erected upon Nittany dolomite and some of the larger caverns have been found to occur below some of the Agricultural buildings and required considerabl stabilization work to prevent settling. As a result, all new construction on the campus is always prefaced by thorough bore hole drillings. In places the Nittany dolomite is strongly bituminous. This formation carries a sizeable amount of chert, either as nodules or more rarely as oolites. The widespread porosity in the Nittany may make it a possible oil reservoir.

BELLEFONTE DOLOMITE: The Bellefonte dolomite is a thick formation, between 1500 and 2200 feet thick, consisting of a dense fine-grained compact dolomite, which breaks with a conchoidal fracture and weathers to a dull white color. At places the Bellefonte is very thinly laminated, at other place the lamination has a rather peculiar appearance (so-called "tiger striped" of Marshall Kay for the Lloydsburg). The Bellefonte dolomite contains a sizeable amount of syngenetic chert and "secondary" quartz. Most of this quartz frequently seems to occur in horizontal veins parallel to the bedding, which may easily have been desiccation features produced by contraction.

A remarkable feature of the Nittany dolomite is the so-called Bellefonte quartzitic sandstone member found near the upper part of the Bellefonte formation. The Bellefonte quartzite outcropping near the axis of Nittany Arch,

Centre County, Pennsylvania, forms a 14-foot arenaceous layer amidst a monotonous 5000-foot series of Lower Ordovician limestones and dolomites. Petrographically it is a varying mixture of two detrital end members: a rounded pure quartz sand and a subangular gravel of dolomite and chert pebbles, which are cemented by two chemical end members: a siliceous (secondary quartz) cement and a dolomite cement. These four end members may mix in all proportions, producing bewildering changes in facies which may take place in less than one mile.

These quartzitic or dolomite-arenite facies dominate locally but pass abruptly into each other. Heavy minerals are approximately 50 per cent tourmaline and 50 per cent zircon. The tourmaline consists of the same 13 types of the Gatesburg, found in the same percentages. Abraded secondary tourmaline overgrowths are present on some tourmaline grains.

Dolomite pebbles can be referred to various Lower Ordovician formations. The quartz sand is directly traceable to the Upper Cambrian Gatesburg and Mines formation 3500 feet below the Bellefonte. The evidence is threefold: (1) Both formations contain identical percentages of the same tangible 13 varieties of rounded tourmaline; (2) The rounded tourmalines in the Gatesburg have developed after deposition striking authigenic overgrowth of colorless sedimentary tourmaline (N_o=1.615; N_o=1.630). The rounded tourmalines in the Bellefonte have identical overgrowths, but abraded and worn; (3) The Upper Cambrian formations are characterized by siliceous oolites. Fragments of the same type of reworked siliceous oolites are present in the Bellefonte. The last two are veritable petrographic guide fossils.

The heterogeneity of composition, the abrupt lithologic changes, and the angularity of the dolomite pebbles indicate simultaneous local erosion of several Gatesburg members and a very brief transport.

This interpretation indicates a 3,500-foot hiatus between the Gatesburg and the Bellefonte. This break implies emergence, truncation, and erosion of the Gatesburg formation somewhere not very far from State College. The relative nearness (possibly less than 75 miles) of the area of emergence and truncation of the Gatesburg is based upon the textural and physical characteristics (coarseness and extreme angularity) of some of the rock fragments within the Bellefonte sandstone which point toward a rather short transport.

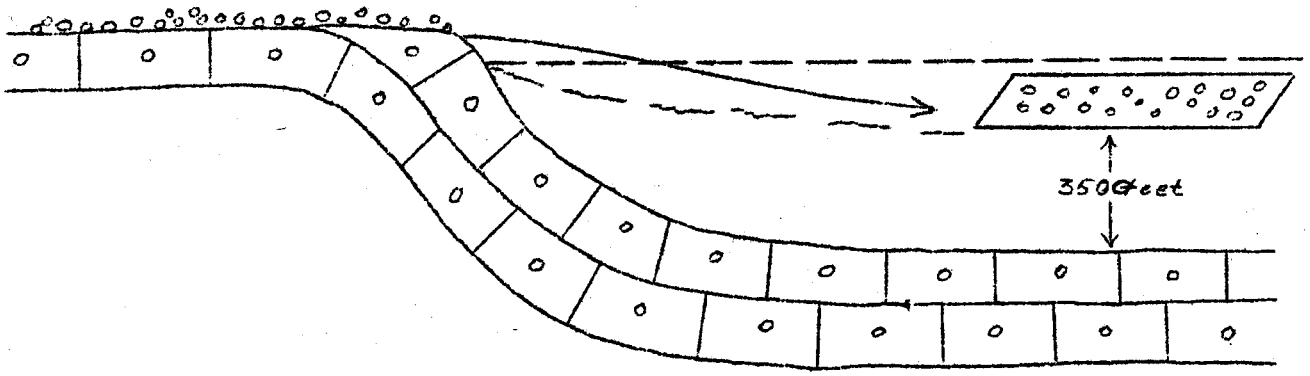
The Gatesburg formation in its original unweathered condition is a mixture of sandy dolomites and calcareous orthoquartzites, with the sandy portions forming 20-30 percent of the whole. A study of the Gatesburg along the Allegheny front shows that upon subaerial weathering the carbonates are leached out and a loose, highly porous sand is produced. This sandy soil makes up the "Barrens" north of State College, and at many places the sand forms highly porous and permeable zones exceeding 30 feet in thickness. This development is not unlike that which took place in the Oklahoma City oil field. Because of the intense tectonic deformation near the Allegheny front, the thicker sand zones produced by recent weathering on the Gatesburg are somewhat local and patchy in their distribution. However, the truncation and weathering of the Gatesburg formation during Bellefonte time apparently were controlled by a much gentler type of uplift, and hence the surfaces of weathering at that time must have been over much larger uninterrupted areas of sand development, which potentially are good oil reservoirs.

MIDDLE ORDOVICIAN PALEOGEOGRAPHY

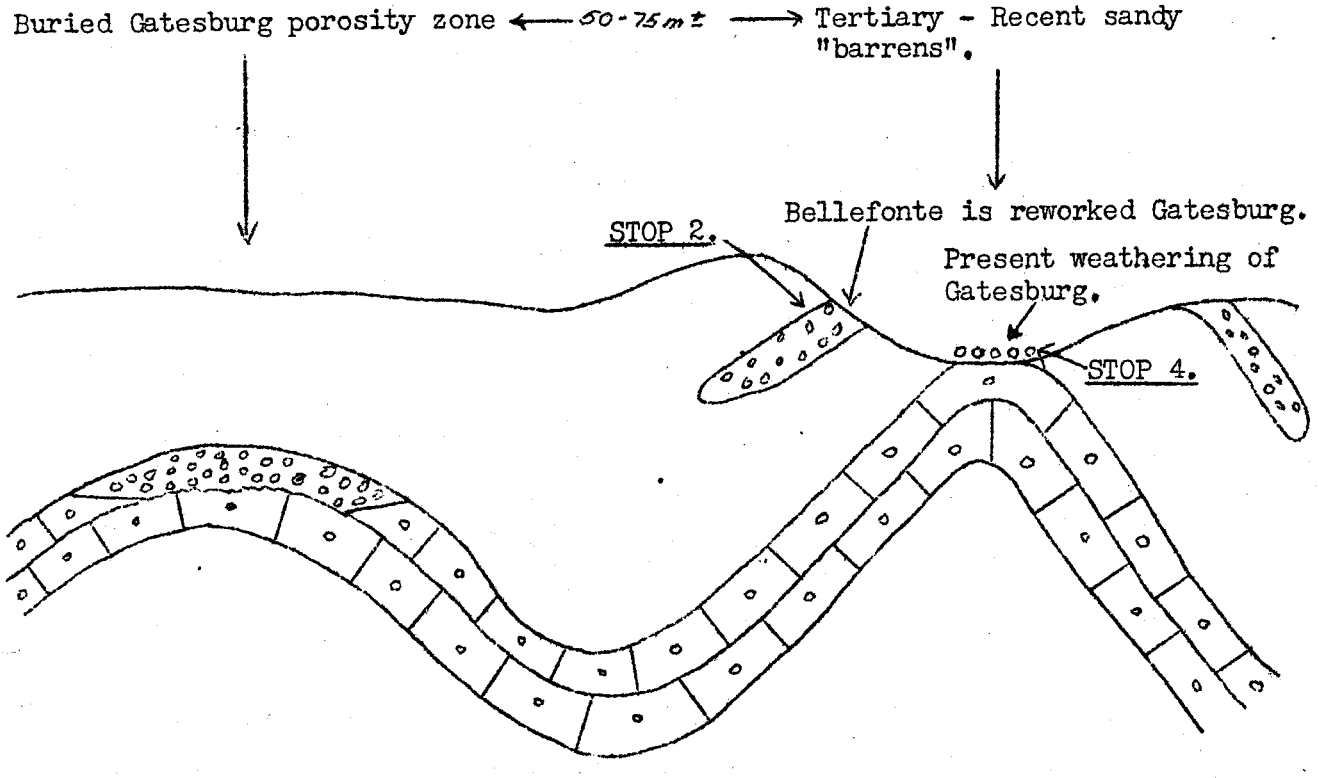
N. W. Pennsylvania — Allegheny Front — State College

GATESBURG - weathered and eroded.
(1) 13 tourmaline types according to definite percentages.
(2) Authigenic overgrowths on tourmaline.
(3) Typical oolites

BELLEFONTE - deposited.
(1) Same 13 tourmaline types and percentages.
(2) Broken and abraded stumps of overgrowths.
(3) Typical Gatesburg oolites and dolomite pebbles.



PRESENT GEOLOGICAL RELATIONSHIPS



Thus, a study of tourmaline varities in central Pennsylvania leads not only to a determination of the genesis of a sandstone member of Middle Ordovician age but also to the reconstruction of central and western Pennsylvania paleogeography during the same time. Finally, it points to the very possible existence of a sizable petroleum reservoir of the Oklahoma City type near the Cambro-Ordovician contact in west-central Pennsylvania, possibly less than 75 miles northwest of State College. These petroliferous possibilities, which are schematically shown in an accompanying diagram, deserve consideration and more detailed study.

STONE RIVER - BLACK RIVER SERIES: According to Butts and Moore these two series consist of the Carlin limestone, the Lowville, and the Rodman limestone. These formations lens in and out considerably. According to Marshall Kay the correlation is somewhat different. Marshall Kay's classification is shown on a separate page. These series are interesting because: (1) They contain the famous Bellefonte (Lowville or Valentine) chemical lime which is extremely pure and is quarried and even mined in the well-known Bellefonte quarries; (2) They also contain a series of meta-bentonites, which are ancient showers of volcanic ash of rhyolitic-andesitic composition. These bentonites are made mostly of montmorillonite and contain a large amount of idiomorphic phenocrysts of biotite (with much rutile) and apatite. The so-called Bellefonte chemical lime is Marshall Kay's upper member of the Curtin limestone or Valentine member which contains 70 feet of very pure limestone extending to the unconformity at the base of the Nealmont limestone. The term "Bellefonte ledge" is applied colloquially to the upper 65 feet of the Valentine member at the American Lime and Stone Company Bell Mine west of Bellefonte. This is not a stratigraphic term, for the footwall in several quarries and mines differs in horizon, and "the chemical lime" at other localities in other stratigraphic units, particularly the Clover and Snyder, has been called Bellefonte lime." (Marshall Kay, p. 1920)

A petrographic study of the relation between Bentonite and limestone hosts in the Oak Hall quarry yielded the following results:

COMPOSITION OF THE INSOLUBLE RESIDUES FROM THE LIMESTONES AT OAK HALL QUARRY

By R. L. Folk

A quantitative mineralogical analysis has been made of the insoluble residues from the limestones at Oak Hall quarry, as part of an unpublished B. S. Thesis. The purpose of the study has been to determine what, if any, effect the volcanism that produced the bentonite layers had on the adjacent limestones. Samples were taken at intervals of from two to six feet along the quarry face, approximately 70 grams of each sample were dissolved in 20% HCl, and the residues examined and percentages extimated under the petrographic microscope.

The total amount of insoluble residue varied from 1.5% to 16.7%, being highest just above the bentonites. The mineral constituents can be divided into two classes: authigenic and

detrital. Authigenic minerals consist of quartz, albite, and minor chert and pyrite. Detrital constituents include quartz, clays, organic matter, with very minor heavy minerals such as zircon, tourmaline, biotite, and apatite.

Quartz occurs in doubly-terminated, euhedral crystals from 0.15 to 0.3 mm. in length. These contain a very large amount of carbonate inclusions, and are highly corroded on the surface. The percentage of authigenic quartz in the samples varied from 0.0 to 5.2%, reaching a maximum above the bentonites, and having several peaks between them.

Chert occurs in very irregular and angular pieces, averaging 0.15 mm. in diameter. It reaches a maximum of over two percent 3' above the bentonites, and is scarcely present otherwise. It is probably authigenic.

Albite occurs in euhedral crystals about 0.08 mm. in length. Crystals are unetched, and contain a moderate number of carbonate inclusions. They are usually polysynthetically twinned. It is present to the extent of 1.4% at the top bentonite, and is generally present throughout the upper part of the section.

Pyrite is present in three forms: (1) as cubes about 0.03 mm. in size; (2) as cubes 0.50 mm. in size; and (3) as long square rods (so-called acicular pyrite) 0.30 by 0.05 mm. It is present in traces in most of the samples, and appears to occur in definite horizons associated with organic layers or areas of dolomitization. Acicular pyrite occurs only at a horizon three feet above two of the bentonites, where it is the only form present.

Detrital quartz occurs as rounded to subangular grains 0.05 to 0.01 mm. in diameter, and is little etched, has few inclusions. It varies from 0.0 to over six percent, and is highest near the bentonites.

Organic matter varies from nine to less than one percent, averaging about 1.6, and remaining comparatively constant. Clays are present in only a few samples in noticeable quantity, often probably being obscured by organic matter. They seem to belong to the kaolin series.

All the heavy minerals are rare, only a few grains being found in most slides. They occur as very tiny grains, about 0.03 mm. in diameter. Apatite is the most abundant, occurring generally throughout the section especially near the bentonites. Zircon is in colorless, rounded grains, with one geniculated twin being found. Tourmaline is euhedral to rounded as green or blue grains showing probable abraded authigenic overgrowths. Biotite is found as dark brown subhedral flakes.

In the opinion of the writer the probable sequence of formation was: Albite - Carbonates - Quartz.

"A" bentonite shows no correlation in effect with "B" and "C" bentonites. However, at a horizon 3 feet above both "B" and "C" bentonites, authigenic quartz reaches a maximum, and almost all the chert and acicular pyrite are found there.

Albite, quartz, and organic matter appear to bear a very close relation to each other. In general, a high amount of organic matter tends to coincide with a high amount of albite and a low amount of authigenic quartz. There is evidence, on the basis of authigenic quartz and apatite, for a period of volcanism midway between "B" and "C" bentonites.

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TRENTON LIMESTONE: The Trenton limestone which reaches a thickness of 600 feet in the region is a thin-bedded, dark, compact limestone, highly bituminous and filled with organic matter and containing a certain amount of clay and a few particles of dark shale. At many places the Trenton is highly fossiliferous. These fossils make it possible to correlate it with the Trenton of New York State (excepting the lower 70 feet of the local Trenton whose age is not definitely known). The Trenton also contains a small amount of volcanic ash.

REEDSVILLE SHALE: Gradually the shale at the bottom of the Trenton changes into the Reedsville shale, a thick formation (1000 feet), made up of brown, greenish, and very dark gray, calcareous and clayey shales. The Reedsville shale passes to the east into the Martinsburg formation of eastern Pennsylvania (a much thicker and coarser grained graywacke).

In the vicinity of State College, the Reedsville shale is a very dark, almost black, highly organic (carbonaceous, very fine grained) rock, with many limey layers and some fossil layers, of which crinoid beds are particularly notable.

The Reedsville shale shows an excellent graded bedding which at places is a regular varving. At many places the coarser beds of the varves may be made of crinoid stem layers, the finer part of the pair being a regular silt. In other varves, the difference is between silt and clay members. This varving can be seen well at the Sky Top outcrop and theoretically should provide a possible correlation of the different portions of the Reedsville formation on the basis of relative varve amplitude regardless of their absolute thickness. This cyclical characteristic is definitely of seasonal origin, but it is not certain what kind of time interval is represented by each varve pair. Possibly it may have been as low as one year.

OSWEGO GRAYWACKE: The Oswego sandstone in the region is a typical graywacke, a dark gray to greenish black, well cemented, very poorly sorted, very tough and resistant rock. This graywacke is fairly coarse grained and within its conglomerate formations portions carries many subrounded to subangular pebbles of quartz (up to $1\frac{1}{2}$" in diameter), jasper, schists, slates, and meta-sandstones or meta-graywacke (some pebbles are even cut by small quartz veins). This Oswego (Bald Eagle) graywacke, at places conglomeratic, is a typical gray, greenish or black graywacke, erroneously described in the literature as

"arkose" or "sandstone." Its composition is extremely constant: around 50% of very angular quartz grains; 10% of clay; 3-5% feldspar (up to 10-15% near base); 40% or more (up to 80%) of rock fragments (slates, phyllites, argillites, schists). The heavy minerals are: idiomorphic or angular tourmaline, zircon, iron ores, very little hornblende, hyanite, some iron carbonates, much pyrite. The Oswego has a fair amount of porosity and permeability which changes considerably from place to place. The hardness and resistance of the rock are due to the strong bonding effect partially caused by secondary quartz cement, and partly are due to straight adhesion between the fine mica flakes of the matrix. The matrix of the rock is mostly illite or sericite clay paste.

The Oswego is characterized by a mixture of graded bedding and cross bedding, as a whole graded bedding predominates. This, plus the dark, reduced color of the Oswego suggests that it was deposited under subaqueous, possibly marine, conditions. An almost total lack of fossils, however, does not make it possible to confirm this.

The Oswego is a good ridge maker and usually forms one member of the double ridges which characterize the erosion features of the Ordivician-Silurian boundary. The Oswego contains a small amount of siderite which upon oxidation passes into limonite giving to the rock a speckled appearance. These specks, and possibly some of the minute weathered slate or phyllite fragments, have been mistaken for feldspar and caused the rock to be mistakenly described as an arkose.

JUNIATA RED BEDS: The Juniata (Queenston) red schist arenite or red graywacke (loosely called "red beds"), can be properly called a "red graywacke." The Juniata contains more shale than the Oswego. Otherwise the petrography is almost identical with the Oswego, excepting that much more rounded quartz grains begin to appear near the top, also round tourmaline and zircon, and numerous red sandstone pebbles. The Juniata is a typical continental flood plain deposit. It is made of a series of sandstone and shale layers with the sandstone member (especially in the eastern portion) paler or lighter in color, whereas the shale members are of a much brighter red. The sandstone members represent a series of coalescing river channel deposits, which have built horizontal sandstone layers. The shale members represent flood-plain deposits. The distinction between channel and flood plain deposits is more distinct toward the east (approaching the source area). Several well-defined channels can be seen at Kishacoquilas near Lewistown, about 35 miles southeast of the Bald Eagle outcrop, but no channels are easily recognizable at Sky Top. However, a few stagnant water bodies, presumably lakes, characterized by reduced, green, very fine-grained shales can be identified at Sky Top (see Stop 6-J).

The Oswego and Juniata are fundamentally alike, excepting that the Juniata was deposited in an oxidizing environment (flood plain) whereas the Oswego was deposited in a reducing one. Both are made up to a large extent of reworked Lower Ordivician fine-grained sediments and low rank metamorphic rocks that were elevated and eroded in the eastern portion of the Appalachian geosyncline during the Taconic revolution. These source beds came partly of sediments from the eastern part of the Allegheny trough, and partly from the Magog trough farther east with a few older(Algonquian) metasediments. There is no material whatsoever from a hypothetical crystalline, igneous Appalachian.

SILURIAN

TUSCARORA QUARTZITE: The Tuscarora quartzite (white Medina of early reports) is a white to gray quartzitic sandstone, with almost no shale. Locally it may be cut by tiny red clayey layers (which, however, form much less than 1% of the rock). The Tuscarora ranges in texture from a coarse-grained, almost conglomeratic rock to a fine-grained, firmly cemented quartzite. The Tuscarora and its eastern facies, the Shawangunk, are made up of round quartz grains cemented by secondary quartz which pass in the coarser facies into easily recognizable quartzite pebbles with little vein quartz. Normally, the Tuscarora contains about 80% of quartz sand grains, cemented by approximately 20% of secondary quartz growing in optical continuity with the central detrital quartz cores. These original detrital quartz grains are very well rounded and sorted. However, the secondary overgrowths give them an angular appearance. Under the microscope, it is easy to see that in many places the quartz grains swim in the cement very loosely, like plums in a pudding, and do not touch each other; thus indicating that the silica cement was introduced at a very early date when the rock had not suffered any compaction at all. The heavy minerals consist of tourmaline, zircon, and some opaque minerals. Again, the tourmaline occurs in frequencies similar to the Gatesburg (with some variations indicating the addition of some pegmatitic material), suggesting that a good bit of the Tuscarora was produced by the reworking of the Gatesburg after its uplift somewhat further east.

The Tuscarora is characterized by well developed crossbedding and ripple marking. It is an extremely resistant rock and the most conspicuous ridge maker of the Appalachian region.

PETROLOGY AND SEDIMENTATION

The Appalachian geosyncline is a typical and perfect example of a geosyncline and its structural development can be effectively studied from the sediments found within its central portion.

During Cambrian time the subsidence of the western portion of the Appalachian geosyncline (Allegheny trough) proceded in a very gentle fashion, mostly by vertical epeirogenic movements which were not very much different from the type of subsidence that took place on the central continental platform or kraton of the American Mid Continent.

This subsidence was gentle (vertical step by step) and involved a considerable amount of frequently recurring movements of the shoreline with many overlaps and offlaps of the sea, and a very considerable reworking of the source material. This subsidence took place over the very flat surfaces of the late Pre-Cambrian peneplain, covered with a deep and completely weathered regolith. This peneplain was interrupted at places by infrequently occurring monadnocks. As a result, there is no definite traceable source area for the Cambrian sediments. On the contrary, they seem to represent an extremely homogeneous mixture throughout the entire Appalachian geosyncline produced by considerable mixing and shifting of source material all over the basin of deposition. This is clear from the fact that they always carry 13 distinct varieties of rounded tourmaline, always in the same frequencies, whereas the average igneous massif is characterized by one or, at the most, two types.

As a result of the peneplanation and prolonged chemical weathering all the unstable minerals were destroyed and only quartz, microcline, tourmaline, and zircon were left. In the vicinity of monadnocks, this stable mineral suite may be enriched by many other igneous minerals.

The slow and recurring movements of the shore resulted in the perfect sorting of the sediment through the reworking of the older sands to form the newer sands slightly above them. Most of the clay and mica flakes were blown away and disappeared through the large-scale dunes developed on these beaches.

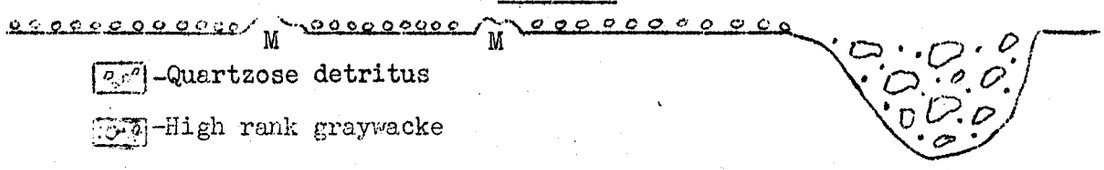
These very shallow seas were a hot bed of chemical activity producing limestone, dolomite, much chemically precipitated silica in the form of chalcedony (chert) or "secondary" quartz, and even such unusual silicates as authigenic microcline, authigenic albite, and authigenic tourmaline. These authigenic minerals recur over enormous horizontal distances throughout the entire Cambrian.

These enormous masses of rounded, almost pure quartzose sands that developed on the old Pre-Cambrian granites and gneisses made up the basic material for the formation of the Cambrian ortho-quartzite and, through the reworking of these quartzites later on, of subsequent Silurian and Devonian quartzites. By the time the geosyncline had subsided sufficiently to exhaust this sand as source material, only chemical precipitates kept on forming. These are the lower and middle Ordovician limestones and dolomites.

SEDIMENTARY AND STRUCTURAL HISTORY OF THE APPALACHIAN GEOSYNCLINE

Allegheny miogeosyncline — Magog eugeosyncline

CAMBRIAN

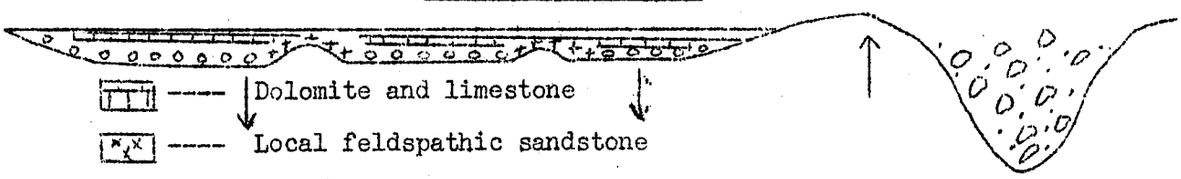


-Quartzose detritus

-High rank graywacke

M - Monadnock

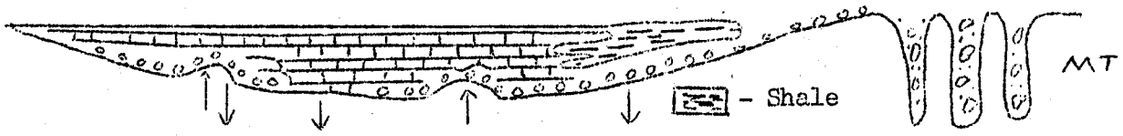
CAMBRO * ORDOVICIAN



---- Dolomite and limestone

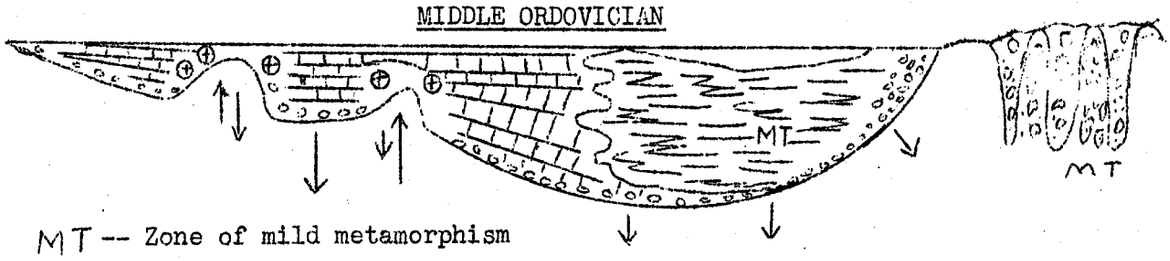
---- Local feldspathic sandstone

LOWER ORDOVICIAN



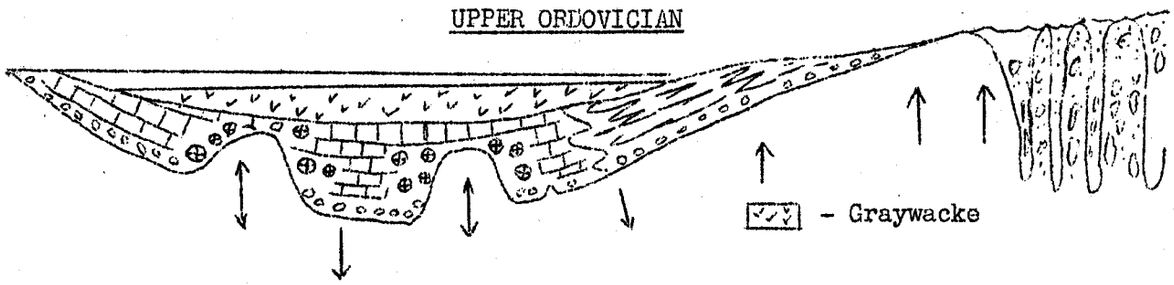
- Shale

MIDDLE ORDOVICIAN



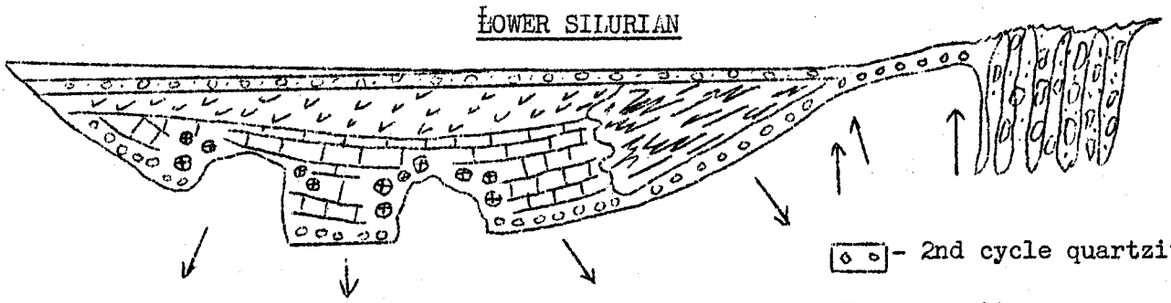
MT -- Zone of mild metamorphism

UPPER ORDOVICIAN



- Graywacke

LOWER SILURIAN

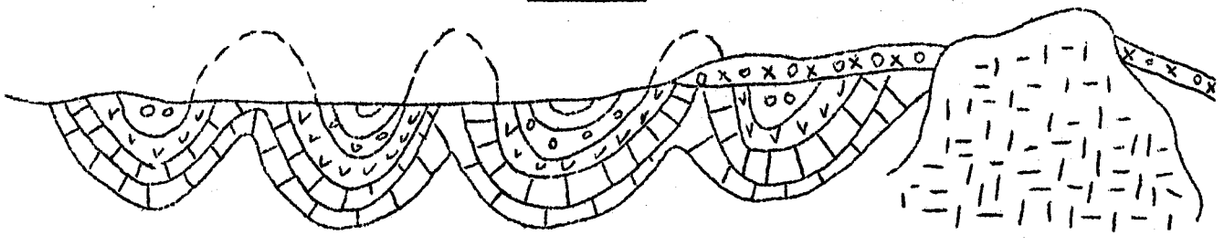


- 2nd cycle quartzite

- Granite

- Arkose

TRIASSIC



While this epeiric type of sedimentation was going on in the western Allegheny trough, the eastern part of the Appalachian geosyncline (or Magog trough) subsided violently and considerably. It formed an eugeosyncline with much volcanic activity, was characterized by the deposition of high rank graywackes. In middle Ordovician time the subsidence of the Allegheny trough accelerated and its bottom began also to be deformed. In Bellefonte time, a local uplift, probably at not a very great distance (50 to 100 miles) west of State College, brought back to the surface the seabottom and produced as a result erosion of the entire Ordovician series, and exposure of the older upper Cambrian Gatesburg quartzite. The erosion of these Cambrian quartzites provided the source material for the Bellefonte sandstone.

By upper Ordovician (Reedsville) time the Magog geosyncline was closed and elevated into the zone of erosion and developed into the source area for the Martinsburg and the Reedsville series. As the Taconic revolution progressed, further uplift in the eastern part of the Allegheny geosyncline closed not only the Magog trough but also elevated into the zone of erosion some of the preceding Martinsburg sediments after having subjected them to mild metamorphism (slate and phyllite development).

The upper Ordovician graywackes (Oswego and Juniata) were formed through the elevation and erosion of both the lower Ordovician meta-sediments of the Magog trough, and also the erosion of the Martinsburg of the Allegheny trough somewhat east of Harrisburg. Hence at this stage the Appalachian geosyncline became autocannibalistic, it was feeding upon its own eastern flank. This, by the way, is typical of most geosynclines which indeed do not get closed at one fell swoop, but get closed gradually in one direction with their upper sediment being produced generally from the reworking of the lower beds.

This process culminated in the lower Silurian when the Cambrian quartzites were uncovered, either in their original orthoquartzitic form, or somewhat metamorphosed to metaquartzites. These large Cambrian masses of clean, quartzose sands helped to build the Tuscarora in a rather brief period of time. It must be remembered that quartzites can form from scratch during very long periods of quiescence through weathering and reworking from many types of source material; but they also can be formed during a much briefer period of quiescence through the erosion and redeposition of an older orthoquartzite or just plain highly quartzose series.

The subsequent history of the Appalachian geosyncline from the lower Silurian to the Pennsylvanian can also be treated in terms of periods of queiscence (limestone quartzitic series of sediments) and of orogenic deformation (graywacke series of sediments). This was finally closed by the complete horizontal deformation of the geosyncline, the intrusion of granites and the formation of Triassic arkoses following faulting. Thus the Appalachian geosyncline represents a complete diastrophic and sedimentary cycle.

THE STATE COLLEGE - TYRONE TRIP

PHYSIOGRAPHY AND STRUCTURAL FEATURES OF THE REGION

The trip covers part of the Bellefonte quadrangle and minor portions of the Tyrone quadrangle. Physiographically this area lies in a region known as the Appalachian Highlands and covers part of the Appalachian Valley and Ridge province and the Allegheny Plateaus which is a part of the Appalachian Plateaus complex.

The Appalachian Valley is sharply separated from the Appalachian Plateau by the so-called Allegheny Front, a striking escarpment that crosses central Pennsylvania and is represented within the Bellefonte quadrangle by the Bald Eagle Ridge. At Sky Top (Locality 6 of the trip) there is a remarkable view from this escarpment and a clear distinction can be made between the two provinces.

The Valley and Ridge province is characterized by longitudinal valleys and intervening long mountain ranges. Many of the valleys are eroded into so-called "canoe-shaped" anticlines. Ridges and valleys are parallel to long anticlines and synclines and the region is fairly well deformed, with dips ranging from 15 to 30 degrees or more.

The rocks of the Appalachian Valley are almost entirely sedimentary and consist of dolomites, limestones, shales, and sandstones, generally greatly folded and faulted. Many of the ridges are formed by the outcrops of vertical strata of quartzite or are capped by resistant sandstone, which protects the more easily eroded underlying shale and limestone. The valleys are as a rule underlain by limestone or shale. The streams commonly follow the long, narrow valleys between the ridges and, where they cross the more resistant strata of the ridges, follow a course at right angles to the ridges.

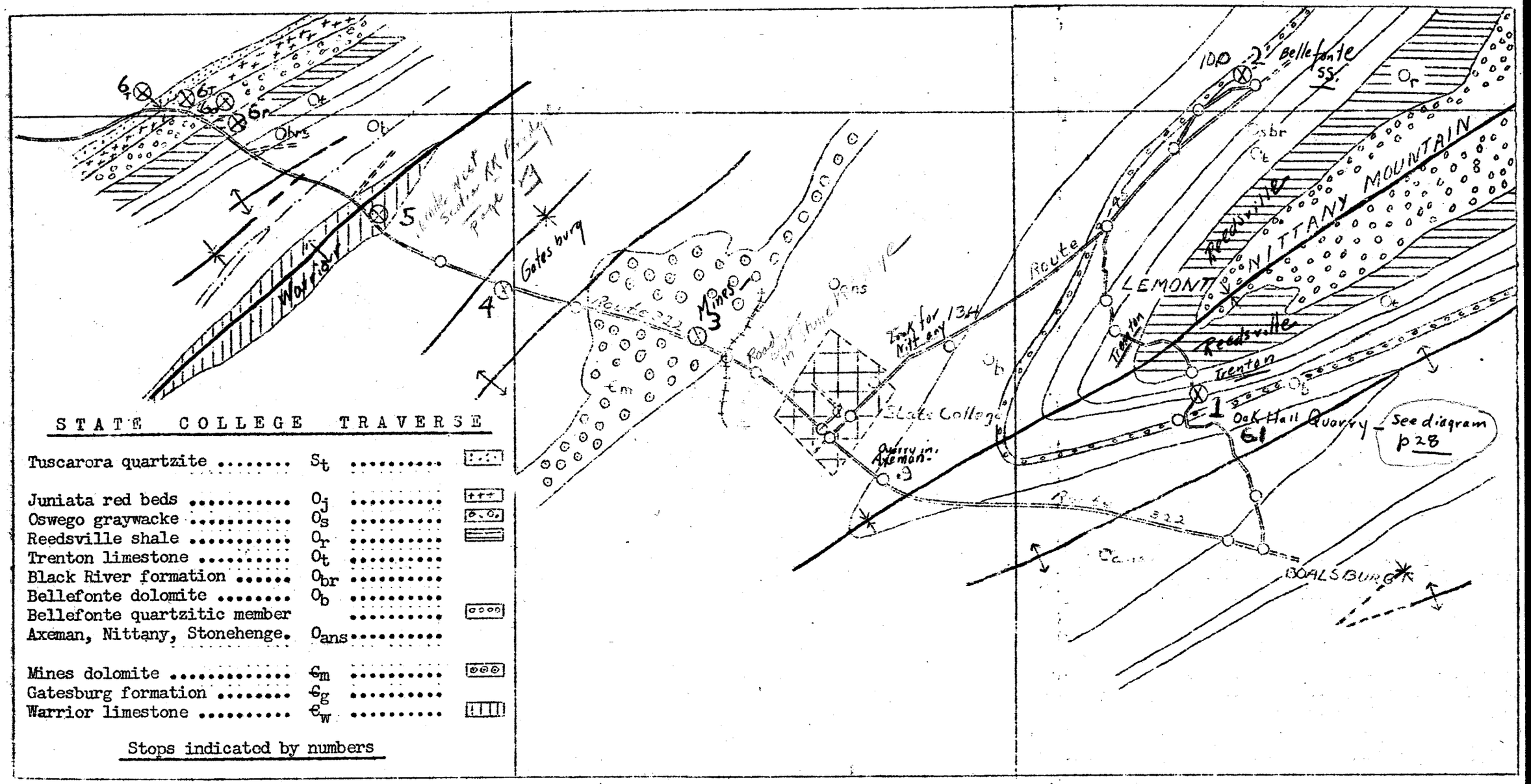
The general altitude of the lowlands in the Appalachian Valley province ranges between 1,200 and 1,400 feet in the Nittany Valley in central Pennsylvania The streams have cut ravines from 20 to 250 feet below the general level of the valleys, and the mountain ridges rise from 500 to 2,000 feet above it.

The Nittany Valley, where State College is located, is formed by the erosion of the Nittany arch, the largest anticline in the central Appalachian region. The Nittany Arch is a large anticline approximately 75 miles long and 10 miles wide at State College. It is bordered on the south by the Seven and Tussey mountains and at State College branches into two wings separated by the Nittany Mountain syncline. The top of Nittany Arch wrinkled by several minor anticlines and synclines of which the Nittany Mountain syncline is the most prominent. The minor anticlines are the Gatesburg and Buffalo Run anticlines, along which the oldest sediments of the region are exposed, and the Penn Valley anticline. The minor synclines on the crest of the Nittany Arch outside of the Nittany Mountain syncline are the Hossler's and the Marengo synclines. All of these folds can be seen on Route 322 between Boalsburg and Sky Top.

A very large fault, the Birmingham fault, is related to the Allegheny Front, and runs somewhat eastward of it. This fault is represented by a fault

valley east of Sky Top and by the striking attitude of the Upper Ordivician and Silurian beds, which not only stand on edge in the Sky Top section, but are also partly overturned. Some minor grabens and horsts produced by the same fault are exposed between Tyrone and Birmingham.

The Allegheny Plateau forms a series of hummocky and subdued mounds and hills, with sub-equal elevations and altitudes of the hill tops, gradually decreasing in height westward. The strata of this division consists almost entirely of shales and sandstones, which, as they include many coal beds, constitute the coal measures of the eastern United States. They are only gently folded with dips 1 to 10 degrees or less. Because of the gentle folding, the courses of the streams are not influenced by long anticlines and synclines; and the topography is a complex of irregularly arranged hills, ridges, spurs, valleys, and ravines, in striking contrast to the prevailing linear arrangement in the Valley on the east.



STATE COLLEGE TRAVERSE

Tuscarora quartzite	S_t	
Juniata red beds	O_j	
Oswego graywacke	O_s	
Reedsville shale	O_r	
Trenton limestone	O_t	
Black River formation	O_{br}	
Bellefonte dolomite	O_b	
Bellefonte quartzitic member		
Axeman, Nittany, Stonehenge.	O_{ans}	
Mines dolomite	ϵ_m	
Gatesburg formation	ϵ_g	
Warrior limestone	ϵ_w	

Stops indicated by numbers

TYRONE TRAVERSE

Tuscarora quartzite ..... S_t ....

Juniata formation ..... O_j ....

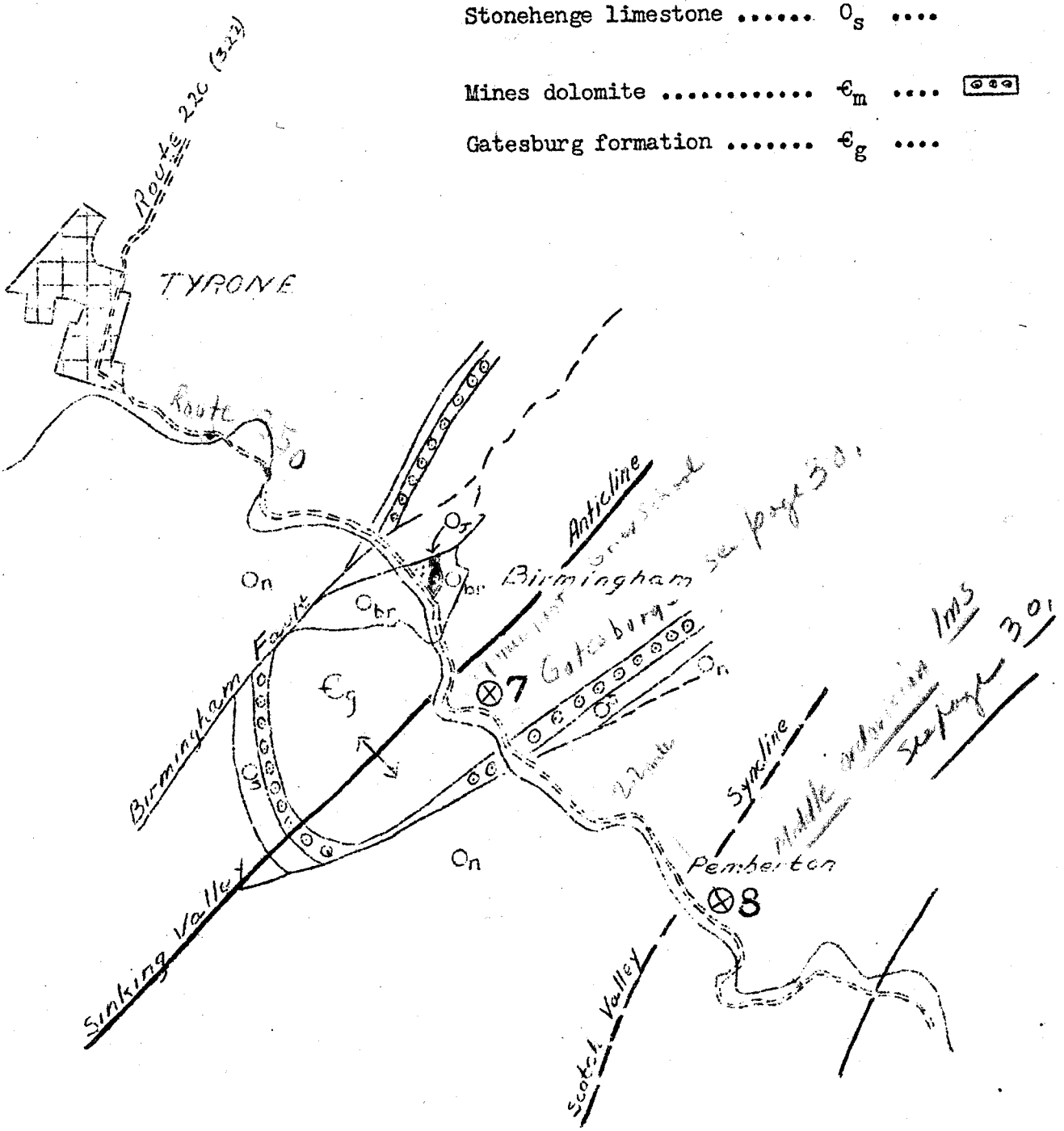
Black River formation ..... O_{br} ....

Nittany dolomite ..... O_n ....

Stonehenge limestone ..... O_s ....

Mines dolomite ..... ϵ_m ....

Gatesburg formation ..... ϵ_g ....



LOG OF THE STATE COLLEGE - TYRONE TRIP

Friday, May 31, 1946

Paul D. Krynine, leader

G. Marshall Kay and F. M. Swartz, co-leaders
R. O. Hotton, S. Oriel, R. L. Folk, J. C. Ferm - field assistants

Mileage	Location
0.0	MINERAL INDUSTRIES BUILDING - START
	Leave 8:45
0.2	Turn left (east) on Route 322 (Atherton Street)
	Running speed 20 m.p.h.
0.9	State College City limits. Quarry on left in Axeman limestone.
	Running speed 40 m.p.h.
4.0	Entering Boalsburg
4.3	Turn left on Oak Hall road
	Running speed 25 m.p.h.
4.8	High school and airport on right. Good view of Mt. Nittany ahead.
6.1	STOP NO. 1 OAK HALL QUARRY
	Arrive 9:15 - Leave 9:45
6.3	Driving past Trenton and Reedsville series
7.1	Cross railroad tracks, entering Lemont.
7.4	Turn right at stop light on old Bellefonte road
8.0	Turn right on Route 45 toward Bellefonte
9.0	Cross roads ahead - proceed to right on Route 45
9.9	Turn left (backwards) on old Bellefonte road

10.0 STOP NO. 2 BELLEFONTE QUARTZITIC MEMBER, OLD DALE SUMMIT SCHOOL

Arrive 10:00 - Leave 10:15

10.6 Turn left on new Bellefonte road towards State College.

13.3 Old iron furnace at left - State College city limits.

13.4 Driving past cavernous Nittany dolomite at right.

Reduce speed to 20 m.p.h. SPEED TRAP AHEAD

14.1 X-G.I. trailer camp at right.

14.8 First stop light (Burrowes Street), State College.

14.9 Second stop light (Atherton Street). Turn right (west) on Route 322 towards Port Matilda.

15.7 Leaving State College - roadcut through Stonehenge formation.

Resume speed to 40 m.p.h.

16.0 Cross railroad track.

16.3 STOP NO. 3 SILICEOUS OOLITE PILE AT THE KRUMRINE FARM

Arrive 10:30 - Leave 10:50

17.5 Crossing top of first ridge in the Gatesburg formation.

18.0 STOP NO. 4 GATESBURG OUTCROP AND ZONE OF WEATHERING
Park car on shoulder

Arrive 10:55 - Leave 11:10

18.7 Scotia railroad bridge.

19.3 STOP NO. 5 WARRIOR LIMESTONE

Arrive 11:15 - Leave 11:30

19.6 Waddle road to right.

20.0 Weathered loose calcite sand - Ordovician.

20.7 Buffalo Run road.

20.9 STOPS 6-R, 6-O, 6-J ORDOVICIAN - SILURIAN BOUNDARY
(Reedsville, Oswego, Juniata formations)

Arrive 11:35 - Leave 1:00

21.5 LUNCH - SKYTOP - magnificent view of Allegheny Plateau.

Arrive 1:00 - Leave 1:45

21.6 STOP 6-T TUSCARORA QUARTZITE

Arrive 1:45 - Leave 2:00

Running speed 30 m.p.h.

23.7 Bald Eagle valley bridge.

23.9 Turn left on Route 220 - 322. Stop sign - careful! Traffic cop usually hiding here.

Running speed 40 m.p.h.

25.3 Tuscarora ridge on left. Devonian (Brailler shales) on right. Entire Silurian and lower Devonian covered up in valley.

26.1 Port Matilda, village limits.

Reduce speed to 20 m.p.h.

26.7 Crossroads in center of Port Matilda. Proceed straight ahead on Route 220.

26.9 Upper Devonian shales on right.

Resume speed 40 m.p.h.

29.6 Devonian shales on right.

35.4 Bald Eagle village. Junction with Route 350; continue on Route 350 - 220.

37.2 Bridge over Pennsylvania railroad.

39.2 Entering Tyrone - sharp curve - drive slowly through paper mill yards.

Reduce speed to 20 m.p.h.

39.7 First stop light - continue straight ahead.

40.1 Second stop light. Junction between Route 350 and Route 220; turn left on Route 350.

40.5 Juniata River at left.

40.7 Cross railroad tracks.

40.9 Junction with Route 550 - stop sign. Continue right on Route 350 across bridge over Juniata River.

Running speed 30 m.p.h.

41.5 Ordovician limestones on left.

41.7 Ordovician limestones.

42.0 Downdropped Juniata formation by side road and bridge. an inlier produced by the Birmingham fault.

42.3 Grier school for girls.

43.0 STOP NO. 7 GATESBURG FORMATION

Arrive 3:00 - Leave 3:30

43.5 Crossroads - continue on Route 350.

Reduce speed to 25 m.p.h.

44.4 Underpass

44.9 Turn left at Union Furnace Quarry.

45.1 Turn into quarry.

45.2 STOP NO. 8 UNION FURNACE (PEMBERTON) QUARRY IN MIDDLE ORDOVICIAN LIMESTONE

Arrive 3:45 - Leave 4:30

45.6 Exit from quarry crossing railroad tracks.

45.6 Turn right on Route 350 towards Tyrone and Altoona.

Running speed 35 m.p.h.

46.2 Underpass

50.2 Junction with Route 550 - turn left towards Tyrone.

50.9 Entering Tyrone.

Reduce speed to 20 m.p.h.

51.1 Stop light and junction with Route 220. Continue straight ahead on Route 220 towards Altoona.

51.3 Turn left, following Route 220.

52.1 Leaving Tyrone.

Resume speed 40 m.p.h.

53.4 Cross Pennsylvania railroad bridge.

54.2 Devonian in road cut.

63.2 Junction with Route 764 - turn right towards Altoona on Route 764.

63.9 Altoona city limits.

Reduce speed to 20 m.p.h.

65.7 PENN ALTO HOTEL, END OF TRIP

Arrive 5:30

DESCRIPTION OF LOCALITIES VISITED DURING THE STATE COLLEGE - TYRONE TRIP

(See Stratigraphy-Petrography-Sedimentation for detailed description and interpretation of formations exposed at each stop)

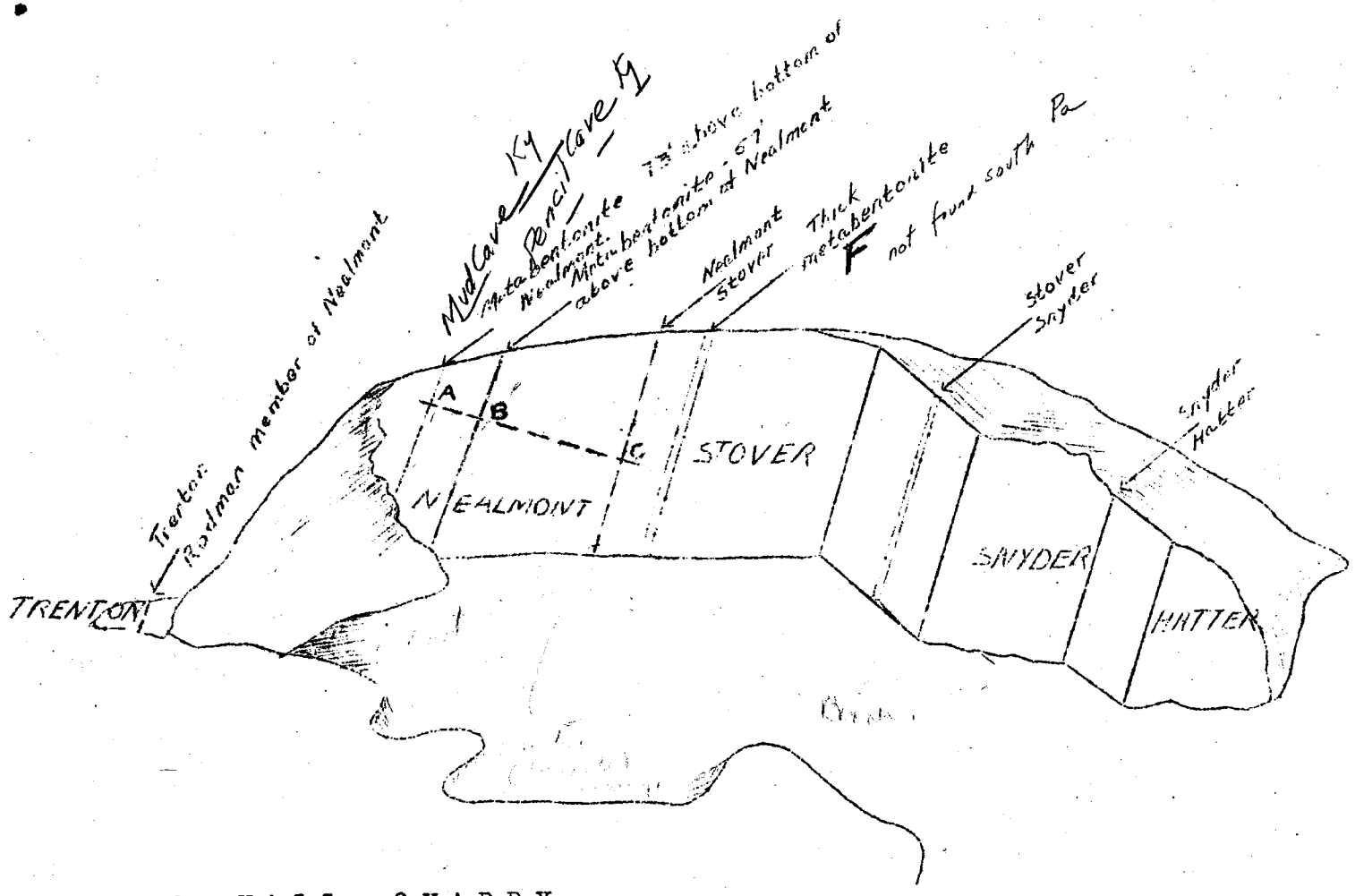
STOP 1 - OAK HALL QUARRY: A good exposure of the Middle Ordovician limestones and related bentonites as shown on the following page. A notable feature of the quarry are desiccation marks, especially mud cracks found in many of the thinner laminated limestones near the footwall.

STOP 2 - OLD DALE SUMMIT SCHOOL, BELLEFONTE QUARTZITE: The low ridge at the old school building northwest of the old Bellefonte road consists of a good outcrop of the quartzitic facies of the Bellefonte sandstone, which dips about 20° to the southeast. The Bellefonte sandstone here is a sub-dolomitic orthoquartzite. Upon weathering some of the calcite cement is leached out, giving to the weathered portions a faintly porous appearance. Red crusts of weathering on the rock are due to the oxidation of ankerite. The Bellefonte quartzite shows abrupt changes in facies and barely three miles to the southwest, this same Bellefonte sandstone passes into a dolomitic conglomerate with only a few quartz grains. A couple of miles later on, it becomes a solid quartzite all over again. Note that at Dale Summit some of the weathered rock fragments contain empty molds of dissolved dolomite pebbles.

STOP 3 - SILICEOUS OOLITE PILE AT KRUMRINE: This oolite pile is the type locality for siliceous oolites, this rock type having been first reported from here in 1890. At the present time good specimens are somewhat hard to find since the best ones have been picked out for museum collections. Note the two types of siliceous oolite, made respectively of black and white chalcedony. Note also the larger chert nodules, many of which have been cracked during dehydration and recrystallization of the original silica gel. Many chert fragments in the pile contain well-developed molds of dolomite crystals that have been leached out during recent weathering. These chert fragments are spread throughout the Mines dolomitic formation and since they are insoluble, they accumulate on the grain as the dolomite is gradually leached away. The pile itself is artificial, having been gathered by farmers from many adjoining fields.

STOP 4 - GATESBURG EXPOSURE AND WEATHERING ZONE ON ROUTE 322: On the right (northeast) side of the highway can be seen three typical rock members of an average Gatesburg cycle, namely, (1) a black to blue massive faintly nodular dolomite (marked "D"); (2) a finer bedded, somewhat platy buff dolomite (marked "B"); and (3) pieces of a somewhat leached orthoquartzite with strong crossbedding, not marked since it occurs mostly as float.

On the left (southwest) side of the highway is developed a typical zone of weathering which produces the sandy soils of the region, known as "The Barrens." This sand is perfectly loose. At places it is rusty from limonitic streaks. In other places, within the same road cut, it is perfectly white. This pure white sand, which is a residual development since it keeps on showing the original crossbedding of the formation, has been observed to form at places



OAK HALL QUARRY

Stratigraphy after G. Marshall Kay, from original sketch by E. S. Richardson in 1943. Petrographic study by R. L. Folk along A-B-C given in text.

a thickness of at least 35 feet and is quarried for building purposes. Such a zone of weathering may form an excellent fluid reservoir (Example - the Oklahoma City oil field) and the petroliferous possibilities of such buried zones of weathering have been already discussed elsewhere in the text.

STOP 5 - WARRIOR LIMESTONE ON ROUTE 322: Several typical Warrior sedimentary cycles are well exposed in this road cut. They show cryptozoon colonies (marked "W") with intervening beds of platy limestone and massive blue limestone. (The latter possibly part of the cryptozoon colony.) Note the numerous oolitic layers and the well-developed bands of edgewise conglomerates. The Warrior outcrop continues down the dip for several hundred feet. There is much hidden volcanic ash in this and related Warrior outcrops.

STOP 6-R - THE REEDSVILLE FORMATION AT THE BEGINNING OF THE SKY TOP OUTCROP: This is a fine-grained, silty, dark shale with calcareous layers. It shows very good graded bedding which passes into well-defined varving. White crosses at the Reedsville outcrop mark the fossil bands, mostly crinoid stem layers, which form frequently the lower part of a varve. The Reedsville is standing on edge.

STOP 6-O - THE OSWEGO GRAYWACKE AT THE SKY TOP SECTION: This also stands on edge and begins to be overturned. At the first white cross, coming from the Reedsville, slicken siding and incipient fault planes are visible. At the second cross there is an efflorescence or bloom of secondary minerals developed on the surface of the outcrop. Those secondary minerals (yellow and whitish) are melanterite, an iron sulphate, which may have been partially changed to coquimbite and quenstedtite. The Oswego shows predominately graded bedding, together cross bedding up. The Oswego in the Sky Top outcrop has considerable porosity, which is higher than normal due to leaching of cements by circulating solution along bedding and fault planes. Note in the coarser grained portions the presence not only of quartz pebbles, but also of small black slate fragments. Notice that the first ridge at Sky Top is made by the Oswego.

STOP 6-J: Between the Oswego and the Juniata Red Beds is found a valley produced by the preferential erosion of the weaker, mostly shaley portions of the Juniata. The sturdier portions of the Juniata consist of pink sandstones and bright red shales. The proportion of the shales in the Oswego is much higher than in the Juniata, although the mineral composition of the sandy portion is the same in both formations. The Juniata at Sky Top is a river plain deposit consisting of alternating, coalescing channel deposits (sandstones) and flood plain sediments (shales).

At "L" is found a thin-bedded green shale which represents probably a stagnant water body in which reduction predominated, presumably a lake. The upper (apparently!) part of the section above this green shale shows somewhat dubious ripple marks or ripple-like sedimentary features. However, since the beds are overturned, these ripple markings (?) are pointing the wrong way. The explanation of this feature is not quite clear.

At "B" veins of barite cut across the Juniata.

STOP 6-T - LUNCH STOP: From the summit of the Bald Eagle ridge at Sky Top can be seen a splendid view of the Allegheny Plateau. The first ridge across Bald Eagle Valley is still a strike ridge of the same type as in the Valley and Ridge province. Beyond that, however, can be seen the dissected surface of the Allegheny Plateau. Note the concordance of the rounded hill tops which presumably represent an eroded peneplane. The amount of wastage of this Cretaceous peneplane has been variously assumed as reaching 300 or even 600 feet. Naturally these figures are highly speculative.

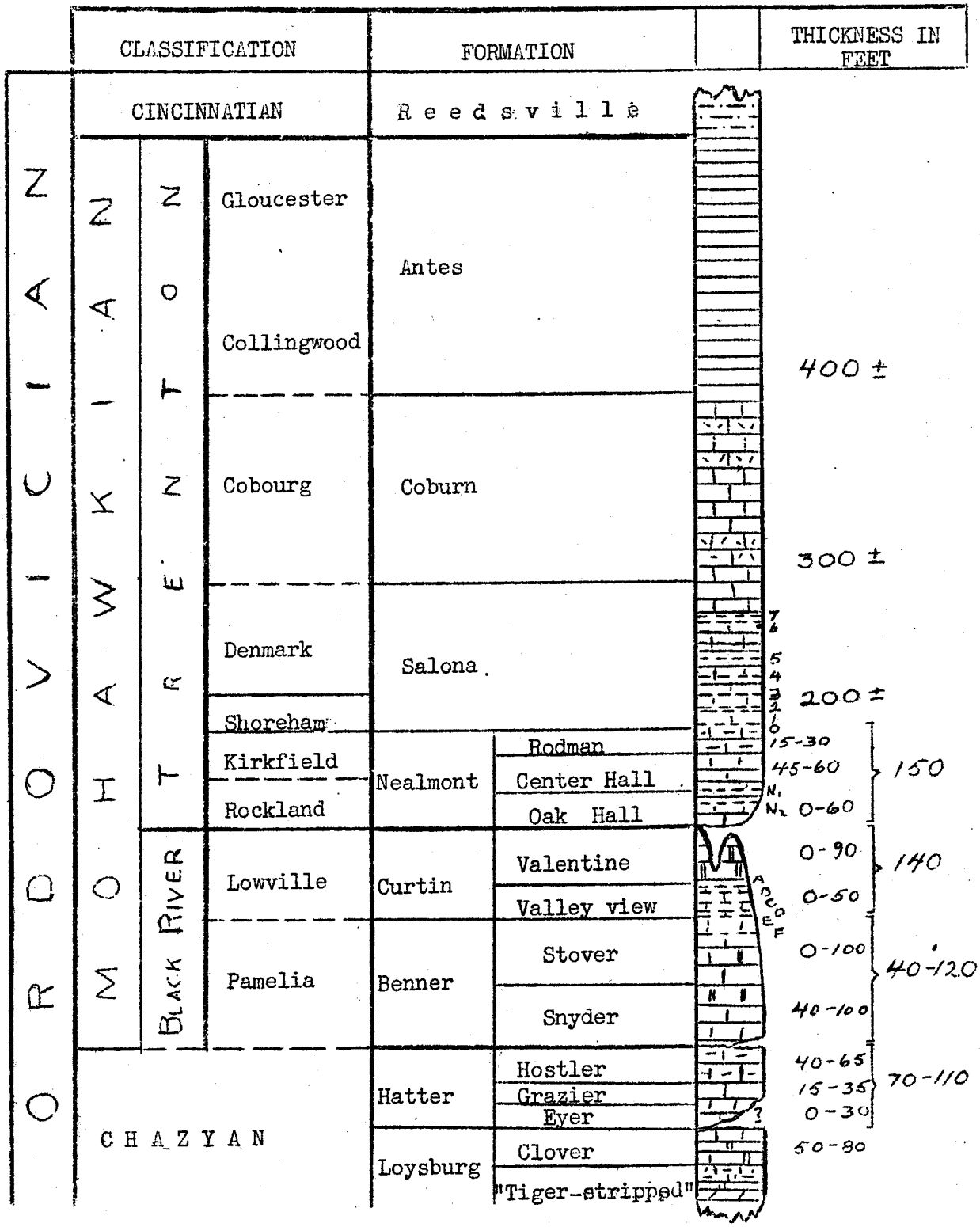
STOP 6-T: Beyond Sky Top is exposed the Tuscarora quartzite, which is completely overturned. It shows excellent crossbedding and ripple marking (at mark "R"). At mark "F" is shown a very fresh portion of the Tuscarora quartzite. The Tuscarora quartzite is the best ridge maker in the entire Appalachian region.

STOP 7 - GATESBURG OUTCROP IN ROAD CUT NEAR BIRMINGHAM: A remarkable Cambrian section, more than 500 feet is exposed in this locality. It consists of 53 cycles of the Gatesburg, which show well exposed black and buff dolomites, quartzites, oolites, cryptozoon layers, and even a single, solitary, very rare shale bed, marked "S". The lower part of this section is not visible in this road cut and should be observed across the Juniata River along the tracks of the Pennsylvania Railroad.

STOP 8 - PEMBERTON QUARRY, AMERICAN LIME AND STONE COMPANY: The railroad cut to the south adjoins the type sections of the Clover, Hatter and Nealmont limestones. 1) The section in this quarry extends from the "Bellefonte" or Loysburg dolomite high into the Salona limestone. As at Oak Hall, the Curtin limestone, which contains the chemical limestone at Bellefonte, is missing by unconformity. Inasmuch as the Benner and Nealmont limestones are as at Oak Hall, and cannot be seen well in the fresh exposures of the active face, it will be best to study only the older and younger beds. 2) The eastern end of the quarry has weathered continuous exposure from the Loysburg dolomite, along the road to the east, into the lower Benner (Snyder) limestone. A fault then repeats the siliceous Hatter formation east of the active operations. 3) The western end of the quarry has continuous weathered exposure from within the Nealmont (Centre Hall and Rodman members) through 200 feet or more of Salona limestone, which has several metabentonites.

STRATIGRAPHY OF MIDDLE ORDOVICIAN LIMESTONES

After G. Marshall Kay



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Allegheny Front Trip
Windber to Huntingdon

by
Frank M. Swartz

The Allegheny Plateau Province of relatively flat Carboniferous rocks, which includes almost all of the western half of Pennsylvania, is terminated on the east by the rise of great anticlinal arches, including those of Morrison Cove and Nittany Valley. Within a few miles these profound upfolds bring to the surface over four miles in thickness of Paleozoic strata, ranging down through the Mississippian, Devonian, Silurian, and Ordovician Systems into the middle part of the Cambrain. The lower part of the exposed sequence consists largely of limestones and dolomites; higher portions are composed mostly of shales and sandstones, the clastics totalling about three miles in thickness.

The Allegheny Front Trip between Windber and Huntingdon has been arranged to provide visits to many though not all of the members of this great sedimentary succession, which bears witness to the long continued, repeated Paleozoic inundations of the Appalachian region, and to the correspondingly vast erosion of the old-land Appalachia on the east. If the day is clear, the trip will also provide panoramic views that finely exhibit the physiographic features of the country, and give insight into the controlling geologic structures. The best of these is seen from Blue Knob fire tower, where from an altitude of about 3200 feet at the tower platform there lies in sight a stretch of country reaching from Laurel Hill on the west to the Broad Top Mountains on the east, and from the vicinity of Tyrone on the north almost to the Maryland line on the south. Fine views are also visible from the points where the route crosses the Allegheny Front east of Windber, and Tussey Mountain east of Williamsburg.

The nature of these panoramas, and of the geologic structures of the area, are indicated by the accompanying block diagram and geologic map. Thus the area of the foothills and valley between the Front and Dunning Mountain is essentially monoclinal, bringing to the surface progressively lower beds of the Devonian and Silurian Systems. Morrison Cove and Williamsburg Valley are cut into the Cambro-Ordovician limestones along the middle of a great faulted and complicated anticline. The sequence then plunges once more into the earth, bringing down the Silurian in and alongside Tussey Mountain, then the Devonian and Mississippian, and finally part of the Pennsylvanian in the coal field of Broad Top Mountain.

The stratigraphic sequence cropping out in these structures is as follows:

Pennsylvanian System:
- Monongahela formation (small remnants on a few hilltops)
- Conemaugh formation, 900 feet
- Allegheny formation, 300 feet
- Pottsville formation, 250 feet

Mississippian System:
- Mauch Chunk red beds, 200 feet (1000 feet in Broad Top area)
- Loyalhanna limestone, sandy, cross-bedded, 50 feet
- Pocono sandstone, 1000 feet, including resistant Burgoon sandstone, 300 feet, above, and green and some red sandstone and shale, below.

Devonian System:
- Catskill red beds, 2500 feet; Butts suggests revival of name Hampshire for these strata
- Chemung shale and sandstone, 2500 feet
- Naples ("Portage") group
  - Brallier shale, 1800 feet
  - Harrell shale, dove gray, fissile, 200 feet
  - Burket black shale, 75 feet
- ?Tully limestone, 2 to 5 feet
- Hamilton shale, 1200 feet (Wahantango of Willard)
- Marcellus black shale, 200 feet (included in Hamilton by Willard as well as by Cooper)
- Onondaga shale and limestone, 80 feet
- Oriskany group
  - Ridgeley sandstone, 120 feet
  - Shriver chert or siliceous limestone, 120 feet
- Helderberg group
  - Mandata shale, 30 feet
  - New Scotland limestone, 15 feet
  - Coeymans limestone, 15 feet

Silurian System:
- Keyser limestone, 140 feet
- Tonoloway limestone, 650 feet
- Wills Creek shale, 450 feet
- Bloomsburg red beds, 50 feet
- McKenzie shale and limestone, 350 feet

(Silurian System Continued)
Clinton group
Rochester shale, 40 feet
Keefer sandstone, 15 feet
Rose Hill shale, 700 feet
(toward northeast, red and green Castanea sandstone)
Tuscarora sandstone
Ordovician System
Juniata red beds, 1200 feet
Bald Eagle sandstone, 600 feet to north, disappearing southward
Reedsville shale, 1200 feet
Trenton limestone, 400 feet
Black River limestones, 250 feet
Chazy limestones, 200 feet
Beekman town group (Canadian System of Ulrich
Bellefonte dolomite 1500 feet
(Axemann limestone, to northeast)
Nittany dolomite, 1200 feet
(Stonehenge limestone, to northeast)
Cambrain System
Larke dolomite, 250 feet
Mines dolomite, 250 feet, with siliceous oolite
Gatesburg sandstone and dolomite, 1750 feet
(The Larke, Mines, and Gatesburg are referred by Butts to Ulrich's Ozarkian System)
Warrior limestone, 1200 feet
Pleasant Hill limestone, Middle Cambrian, 200 feet plus
Concealed below present level of erosion; strata of the underlying parts of the Cambrian are brought up in the South Mountains to the east near Gettysburg

The conditions and locations of exposure along the trip route are summarized in the following discussion.

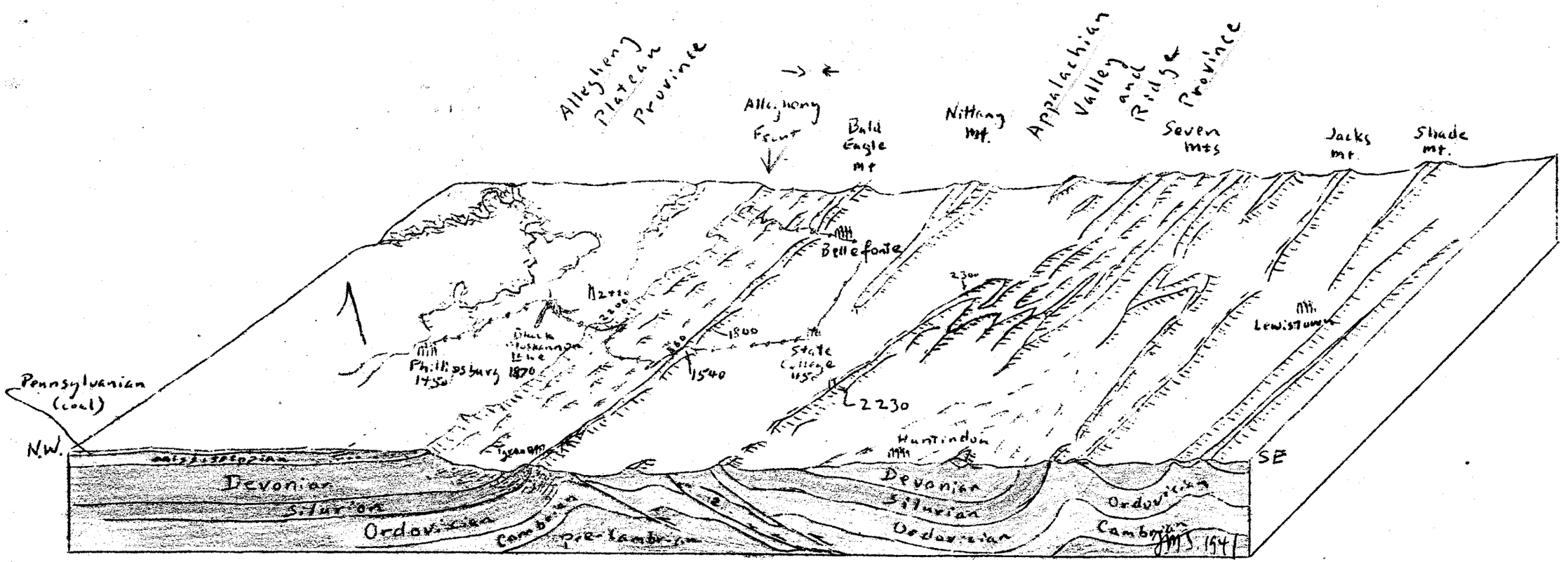
Take highway No. 56 from Johnstown through Scalp Level and Windber, crossing the Conemaugh and Allegheny formations. The Pottsville and Mauch Chunk rise to the surface just west of Ogeltown (Bedford quadrangle). At Ogeltown, the Loyalhanna limestone is well exposed in a quarry.

Stop at summit of Allegheny Front, crossed by Highway No. 56 at an altitude of 2600 feet. Park cars at summit and walk partway down hill. There is a fine view to the east and south, to and beyond ridges made by Tuscarora sandstone. To the east, Dunning Mountain, its height about 2200 feet, has a summit scarred by workings for ganister rock used in the manufacture of silica brick. Followed southward, Dunning Mountain is offset by the syncline at Dunning Cove, and is then known as Evitts Mountain. Bedford and nearby Bedford Gap in Evitts Mountain are clearly visible on a good day. The anticlinal Wills Mountain rises just west of Bedford, its western limb cut lower and breached by gaps. West of Wills Mountain, and almost 15 miles farther south, is the tip of Savage Mountain, where the Pocono and Pottsville are brought down by the syncline of the Frostburg coal field.

In the foreground, the Front drops steeply to 2100 feet near the base of the Pocono, then extends into foothills in which the limits of the red Catskill are visible in the soil. Beyond are seen the brownish soils of the Chemung and lower beds, and the Oriskany sandstone rises to the surface in the gentle anticline of small Chestnut Ridge toward Schellsburg.

The lower part of the Burgoon sandstone is well exposed along the highway near the summit; this sandstone where buried farther west is widely known to drillers as the "Big Injun sand". Downslope along the highway are exposures of lower parts of the Pocono, including red beds presumably representing the Patton shale member. Along this part of the Front the base of the Pocono has been drawn at the base of a 180-foot body of greenish sandstone. The lower Pocono is believed to correspond to the Cuyahoga of Ohio, the upper part to the Logan beds.

Return to cars, and continue south on Highway No. 56 to Pleasantville, crossing the broad belt of Catskill red beds, the lower part fairly well exposed, followed by crops of the uppermost Chemung, the underlying parts of that formation being mostly covered. At Pleasantville turn left on blacktop road to Weyant, following about along strike of basal Brallier and Harrel. Burket black shale is exposed along roadside about 1 mile south of Weyant. At Weyant intersect highway No. 869; follow 869 north to Pavia, on Ebensburg quadrangle, where there are extensive exposures of Catskill red beds. At Pavia turn right on dirt road ascending Blue Knob to the Blue Knob fire tower.



View, looking northeast, of block neighboring State College

Length, 50 miles, width about 40 miles

STRATIGRAPHIC SEQUENCE AND GENERAL STRUCTURE OF THE ALLEGHENY FRONT AND NITTANY VALLEY - MORRISON COVE REGIONS OF CENTRAL PENNSYLVANIA

by
Frank M. Swartz

The Allegheny Plateau Province of relatively flat carboniferous sediments, which embraces most of western Pennsylvania, is terminated near State College and Altoona by rise of the great anticlinal arches of Nittany Valley and Morrison Cove. Within a few miles those profound upfolds bring to the sur ace over four miles of Paleozoic Strata, ranging down through the Mississippian, Devonian, Silurian, and Ordovician Systems into the Upper and at a few points the Middle Cambrian. The lower part of this exposed sequence consists largely of limestones and dolomites; higher portions are composed mostly of shales and sandstones, the clastics totalling nearly three miles in thickness.

The Nittany Valley and Allegheny Front Trips have been arranged to provide visits to many though not all of the members of this great sedimentary succession, that bears witness to the long continued, repeated paleozoic inundations of the Appalachian region, and to the correspondingly vast erosion of the old-land, Appalachia, on the east. At some points there are panaroncia views that finely exhibit the physiographic features of the country, and that give insight into the controlling geologic structures.

The geomorphology and geologic structure of the region are illustrated by the accompanying block diagram and geologic map. The stratigraphic sequence, with generalized thicknesses, is as follows:

Pennsylvanian System:

Monongahela Formation (eroded)
Conemaugh Formation 900 feet
Allegheny Formation 300 feet
Pottsville Sandstone 100 to 200 feet

Mississippian System:

Mauch Chunk red beds, 200 to 300 feet,
100 feet in Broad Top area.
Loyalhanna limestone, sandy, cross-bedded, 50 feet.
Pocono Sandstone 800 to 1000 feet, including at top
Burgoon Sandstone, 250 to 300 feet.

Devonian System:

Catskill red shale and sandstone 1500 to 2000
Chemung shale and sandstone 2500
Naples group, 2200 feet:
Brallier shale 1800 feet
Harrell shale, dove gray, fissile, 300 feet
Burket black shale 75 feet.

Tully (?) Limestone 2 to 5 feet
Hamilton Group, 1400 feet:
  Mahantango Shale, or greenish Hamilton shale, 1200 feet.
  Marcellus black shale, 200 feet.
Onondage Shale and Limestone 80 feet
Oriskang Group, 240 feet:
  Ridgeley Sandstone 120 feet
  Shriver chert or Siliceous Limestone 120 feet
Helderberg Group, 60 feet:
  Mandata Shale 30 feet
  New Scotland Limestone 15 feet
  Coeymans Limestone 5 to 15 feet.

Silurian System:

Keyser Limestone 140 feet
Tonoloway Limestone 600 feet
Wills Creek Shale 450 to 500 feet
Bloomsburg red Beds 50 to 100 feet
McKensie Shale and Limestone 350 feet
Clinton Group, 750 feet
  Rochester Shale 40 feet
  Keefer Sandstone 15 feet
  Rose Hill Shale 700 feet
  (to northeast, red and greenish Castanea Sandstone, to 75 feet)
Tuscarora Sandstone 500 feet.

Ordovician System:

Juniata Red Sandstone and Shale, 1200 feet
Bald Eagle or Oswego Sandstone, 600 feet
Reedsville Shale, 1200 feet
Trenton Limestone, 600 feet
Black River Limestone Group
Chazy Limestone Group
Beekmantown Series (Canadian System of Ulrich) 3500 to 4000 feet:
  Bellefonte dolomite, 1500 to 2000 feet
  Axemann Limestone, 500 feet, disappearing to southwest near Williamsburg.
  Nittany dolomite, 1200 feet.
  Stonehenge Limestone, 600 feet, disappearing to southwest near Williamsburg.

Cambrian System:

Larke Dolomite, 250 feet near Williamsburg,
  zero near State College.
Mines dolomite, with siliceous oolite, 250 feet.
Gatesburg sandstone and dolomite 1750 feet
  (The Larke, Mines, and Gatesburg have been referred by Butts to Ulrich's Ozarkian System.)
Warrior Limestone 1200 feet
Pleasant Hill Limestone, 200 feet, Middle Cambrian.
Waynesboro (?) Shale (in small fault block in Morrison Cove.)
Concealed below level of erosion.

Horse Shoe Curve Trip
Ebensburg and Hollidaysburg Quadrangles

by
Frank M. Swartz

The cuts along the main line of the Pennsylvania Railroad in the vicinity of the Horse Shoe Curve, west of Altoona, Pennsylvania; expose one of the finest displays of the later Paleozoic Strata found along the course of the Allegheny Front. Beginning at Tunnel Hill on the eastern outskirts of Gallitzin, in the northeastern part of the Ebensburg quadrangle, the section crosses in descending order some 8000 feet in thickness of sand and clay deposits, from the base of the Pennsylvanian Conemaugh formation to the Burket black shale at the bottom of the Upper Devonian. The strata rise to the surface with a gradually increasing dip, induced by the great anti-clinal arches of Nittany Valley and Morrison Cove, and thus produce the transition from the more westerly Allegheny plateau region to the more easterly Appalachian Ridge and Valley Province.

Especial appreciation must be accorded to the Pennsylvania Railroad for granting permission for the trip. Arrangements were made through the courtesy of Mr. D. E. Smucker, Superintendent of the Pittsburgh Division of the Railroad; and the trip will be made under the direct supervision of Officer Shinn and his assistants from the Railroad Police Force at Altoona. Releases must be signed in duplicate by each person the night before the trip is made. Great care will be necessary during the trip to prevent accidents, as the train traffic is very heavy. Due to train conditions, it will be difficult to gather at exposures in large groups, and it will be necessary to resort to an unusual degree to use of these guidebook descriptions.

The stratigraphic sequence of the classical Horse Shoe Curve area has been described comprehensively by Platt and Sanders (1877,1881), and more especially by Butts (1905,1918). Some faunal information has been furnished by Kindle (1906), and by Willard (1933) who has added comments bearing on correlation of the strata (Willard 1935, 1939).

The account presented on following pages has been prepared by the present writer from traverses made with the assistance of S. S. Oriel, J. C. Ferm, and A. R. Palmer. Landmarks, including mileposts and signal towers, have been recorded to aid identification of horizons. The distance measurements of the traverses were made by measuring wheel and are subject to small corrections. Compass bearings are magnetic. The course of the trip, and positions of outcrop stations and landmarks, are shown in the index maps, Figures H1 and H2. Other sketches illustrate stratigraphic and faunal features.

The route followed from the Penn Alto Hotel in Altoona will first be recorded, and then the exposures studied along the railroad right-of-way will be described.

miles

0 Penn Alto Hotel, at 12th Street and 13th Avenue, Altoona, Pa. Take chartered bus at the hotel.

Turn right on 13th Avenue. At 0.1 to 0.2 miles, Burket black shale, to be seen at Burket at the end of the Horse Shoe Curve trip, is exposed in banks along 13th Avenue.

0.4 Turn right on 16th Street and then immediately bear left onto Washington Avenue, which continues into Route No. 36.

Greenish shales and sandstones are locally exposed along highway, as at 1.1, 1.3, and 1.4 miles.

2.6 Basal red beds of the Catskill formation are exposed at the summit of a prominent foothill, from which there is a fine view of the main escarpment of the Allegheny Front, made by the Burgoon sandstone of the Pocono. The highway then drops to a broad valley.

4.0 Red and some green sandstones of the Catskill group are exposed as the highway begins to ascend the mountain.

Green sandstones, presumably basal Pocono, crop out at 4.2 to 4.25 miles; reddish sandstone at 4.4; greenish sandstone and shale, partially concealed, 4.4 to 4.6 miles.

Thick-bedded Burgoon Sandstones are exposed 4.8 to 5.4 miles, well up the escarpment of the Front; in clear weather, there should be fine views back toward the east.

Some reddish shale and sandstone of the Mauch Chunk are exposed at 5.8 miles.

6.2 At top of mountain, turn left toward Ashville. Buckhorn Rusty Coal Mine to left at 6.5 miles. Sandstones are exposed at 7.3, shale at 7.7 miles.

7.8 Turn left on road to Coupon (1 mile) and Gallitzin (6 miles).

8.9 Coupon Village.

The road is crossing Allegheny and Conemaugh beds of the moderately dissected surface of the Allegheny Plateau region. At 10.15 and 10.5 miles there are fine views eastward toward the crests made by the upreared Burgoon sandstone.

11.1 Side road on left leads to Horse Shoe Curve. Continue straight. At 12 to 13 miles, the road follows a low ridge capped by the Ebensburg sandstone of the Conemaugh formation; as the surface descends toward Gallitzin, there is a fine view of the environs of Sugar Run Valley toward the left, of the headwater region of the Conemaugh toward the right.

At 13.4 a road turns sharp left to Gallitzin; continue straight on road beginning a return to Altoona; Conemaugh beds are exposed at the intersection.

miles

13.8 Leave busses and take a dirt road to left, walking to east portal of the east-bound or southern tunnel of the railroad. The busses will continue along the Sugar Run road, passing Blair School at 14 miles, to a small turnout on the right side of the road at 16 miles, opposite entrance of a dirt road, and 0.25 miles west of the lower bridge over Sugar Run.

STOP No. 1. Upper Allegheny. The basal part of the Conemaugh and uppermost Allegheny are exposed for a distance of 620 feet east of the portal of the east-bound tunnel of the railroad. The Upper Freeport coal, its top the Summit of the Allegheny, is well shown, as is the Upper Freeport limestone. Following the cyclothem theory advocated by Weller and Wanless, the Upper Freeport limestone would represent the acme of the depressive phase of the cyclothem of the Lower (?) Freeport coal of this section; the cyclothem of the Upper Freeport coal would presumably begin with the sandy beds 3 to 4½ feet beneath this coal, and would continue into beds of the Conemaugh formation.

The following strata are exposed at stop 1; thickness are given for individual beds, and totals will be carried downwards from the top of the Upper Freeport coal.

Pennsylvanian System

Conemaugh Formation	Feet
Concealed on hill above tunnel.	
Thin-bedded greenish shale, exposed near and above east portal of tunnel.	40
Exposed, basal Conemaugh shales	40

Allegheny Formation

Upper Freeport Coal:	6	6
Grayish fireclay above, concealed below	3	9
Thin-bedded, silty sandstone, some shale	1½	10½
Thin-bedded, greenish shale	6½	17
Upper Freeport Limestone: Thin- to medium-bedded, impure limestone and some interbedded shale, especially at 14 to 16 feet below top. On upper 8 feet, the limestones are medium-bedded, and weathered with ferruginous surfaces lighter in color than those of next lower beds. South of tracks, base is at 408 feet traverse.	25	42
Thin-bedded shale, weathering greenish. Base near signal tower at 612 feet traverse.	12	54

	Feet	
Lower (?) Freeport Coal, weathered, poorly exposed. about	1	55
Thickness of Uppermost Allegheny Beds exposed at Stop 1.	1	55

(First Signal Tower, at 612 feet traverse)

Concealed for long distance, to 5220 feet traverse, the west-bound tracks joining the east-bound. There are old coke ovens south of the tracks from 1700 to 2300 feet traverse; the Bennington mine south of Sugar Run is about opposite 4500 feet traverse. Neighboring hills to north and south rise to elevations of 2300 to 2500 feet, and are capped by basal beds of the Conemaugh formation.

Thickness	250?	300?

(Second Signal Tower at 5220 feet traverse)

STOP No. 2. Lower Allegheny, Upper Pottsville. The basal part of the Allegheny formation, including the Brookville Ceal, and the Homewood sandstone and Mercer shale of the upper part of the Pottsville, are exposed in cuts from 5220 to 6432 feet of the traverse.

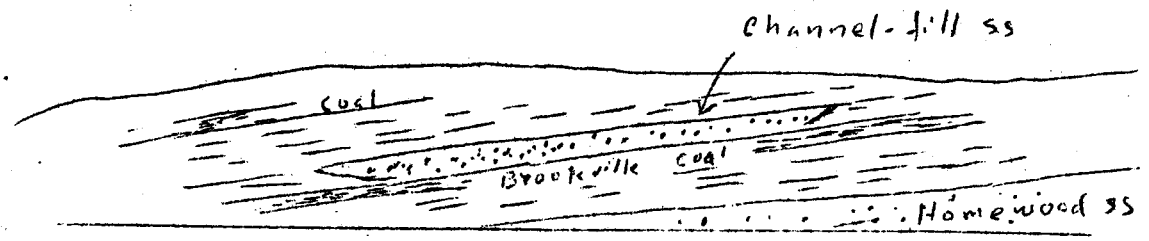
The especially interesting features at this place are (1) The channel-fill sandstone above the Brookville coal, from 5475 to 5740 feet traverse; this should represent the initial deposit of a post-Brookville cyclothem; (2) The fine Lepidodendron fossils in the strongly cross-bedded Homewood sandstone, 40, 55, and 65 feet east of the third signal tower; (3) The channel-fill thickening of the Homewood at the east end of the cut, that lends an appearance of flexuring to the base of the Homewood.

The succession at Stop 2 is as follows:

Allegheny Formation:

Thin-bedded, strongly cross-bedded sandstone and some shale	10	310
Coal bed.	3	313
Thin-bedded shale with thin, irregularly-bedded interlayers of sandstone; scour and fill structures occur near the west end of the cut.	10	323

	Feet	
Thin- to medium-bedded, very irregularly-bedded sandstone, filling a shallow, broad channel from 5475 to 5740 feet traverse, and reaching a maximum of 7 feet thickness.	7-0	330

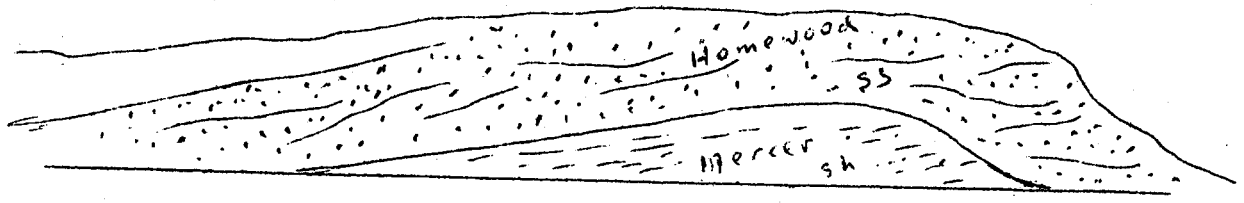


Thin-bedded shale, cut out where channel-fill sandstone is present.	0-7	330
Brookville Coal	5	335
Concealed below; at top are 3 feet of grayish fire clay. Thickness variable	5-10	340

Exposed thickness of basal part of Allegheny Formation.	40-45	
Total thickness of Allegheny around		300 to 340

Pottsville Formation

Homewood Sandstone: Thick-bedded, decidedly cross-bedded, strong, medium-grained, somewhat micaceous sandstone, becoming less massive near top. The base of the rock forms a broad arch, not due to flexuring but because at the east end of the bluff the sandstone cuts deeply by scour and fill into the Mercer shale as suggested in the following sketch.



Land plant fossils are common in the Homewood, and exceptionally fine Lepidodendron specimens are located, on north side of cut, at 40, 55, and 65 feet east of the third signal tower at 5922 feet traverse. Please leave specimens for future visitors. Dip 3° NW. Thickness 15-22 feet, thickening in channel-fill to more than 40 feet.

	15-22	362

		Feet
Mercer clay and shale. Thin, irregularly-bedded fine-clay and shale, above; medium-bedded, fine-grained micaceous sandstone and some shale, below. On the north side of the cut, these strata reach their maximum exposed thickness at 6230 feet traverse, then are truncated to track level at 6350 feet.	18-0	380
Concealed across small valley east of former Bennington settlement, to 7115 feet traverse.	20?	400

STOP No. 3. Pottsville. The Conoquenessing sandstone of the Pottsville formation is finely exposed in bluffs at 7115 to 7890 feet of traverse, with some basal Mercer present locally at the summit. The marked cross-bedding, and land-plant fossils give evidence of the non-marine origin of the sediments.

The Pottsville conglomerate receives its name from Pottsville in the anthracite fields of eastern Pennsylvania. Near Tamagna, east of Pottsville, Ashburner (1883) reported thicknesses of 1130 to 1300 feet of Pottsville, the rock consisting throughout of conglomerates and sandstones, with a few through streaks of coal, and with some subordinate red shale in the lower 400 feet.

Southward from southwestern Pennsylvania the Pottsville deposits likewise thicken, attaining a maximum of not quite 4000 feet in southern West Virginia. The Pottsville of southwestern Pennsylvania is believed to represent horizons close to the top of the more southernly Pottsville sediments.

The thickness of 100 to 120 feet of the Pottsville east of Gallitzin is representative of the thicknesses known in wells toward Pittsburgh, where the formation is in part represented by the salt sands.

The Pottsville beds at Stop 3 have the following characters:

Conoquenessing Sandstone. Thick-bedded, strongly cross-bedded, somewhat micaceous sandstone, tending to break along the cross-bedding into slabs about 2 to 6 inches thick. Plant fossils occur on boulders at 7300 feet traverse. Irregular, limonite encrusted joint surfaces are prominent at 7300 to 7350 feet. One- to two-foot bodies of shale occur locally at 2 and 20 feet above base. The top of the sandstone remains above track level at west end of cut; at top of bluff, as much as 10 feet of basal Mercer shales are locally present on the irregular upper surface of the Conoquenessing; to 7890 feet traverse.	50-60	450
Thickness of Pottsville around		100 to 120

(Milepost 246 at 7674 feet traverse)

Concealed. Probably Mauch Chunk shale for the most part but may include some basal Conoquenessing. To 9306 feet traverse.	150?	600?

(Signpost 4/3 at 9186 feet traverse)

STOP No. 4. Mauch Chunk Mississippian. Mauch Chunk beds are exposed from 9306 to 10,746 feet traverse, and include an upper shaly member, a lower-middle sandstone member of Pocono-like facies and a lower shale and sandstone member. Continue across the upper member and stop at 10,000 feet at top of sandstone member, likewise examining basal conglomerate of this member near Signal Tower No. 2454 at 10,780 feet traverse.

The Mauch Chunk shale was named from Mauch Chunk on the Lehigh River, where it is 2168 feet thick according to Lesley's Final Report, and consists almost wholly of red shale and sandstone. These continental red beds are reported to reach 3000 feet thickness a little farther west, and north of Harrisburg the thickness may increase still further. Thicknesses of about 1000 feet are reported in the Broad Top basin 25 miles southeast of Gallitzin.

The Mauch Chunk beds extend below the surface in western Pennsylvania as the Thin Red Rock associated with the Big Lime or Greenbrier limestone. The Greenbrier crops out in Pennsylvania along the flanks of Chestnut Ridge, replacing shaly Mauch Chunk beds, and having red shale tongues beneath it as well as above. The Greenbrier calcareous deposits thicken southward, reaching 600 feet in the type Greenbrier region in West Virginia, 1000 feet in Mercer County. The greenbrier of the Chestnut Ridge region contains abundant fossils furnishing correlation with the Maxville limestone of Ohio.

At Stop No. 4 deposits of Greenbrier facies are lacking, and marine faunas have not been observed in the Mauch Chunk.

The succession is as follows:

Mississippian System
Mauch Chunk Shale
Upper Shaly Member

	Feet	
Silty, in part calcareous mudrock, red 10 to 25 feet below top, with reddish variegations in lower part.	42	642
Medium-grained, buff sandstone, at 9684 feet traverse.	3-10	645
Silty mudrock, variegated red and green; bedding irregular, wedging in and out. To 10,006 feet traverse.	15-20	660

Exposed thickness upper shaly member 60

If overlying concealed interval be included 210

Sandstone member of Mauch Chunk:

Thick-bedded, strongly cross-bedded, buff- to whitish-weathered, somewhat micaceous sandstone of Pocono-like aspect. Top is channel-cut near middle are local 1-foot lenses of fine conglomerate, the matrix limy; many parts of sandstone have one- to two-inch pits, formed in part at least by solution of flat to rounded limy fragments. Sand grains mostly quartz, with

		Feet
some clayey (sericitic-illitic?) interstitial material. This sandstone, as well as parts of the red shale members of the Mauch Chunk, plausibly interfingers southwestward with the Greenbrier limestone; in the Broad Top region to the southeast, it evidently becomes incorporated in the Pocono sandstone as commonly understood. To 10464 feet traverse.	35	695
Concealed, the interval probably all represented by sandstone of next bluff. To 10,746 feet traverse.		695
(Signal Tower No. 2454 at 10,782 feet traverse)		
Thick-bedded, cross-bedded sandstone, conglomeratic below, and having at its base a coarser, zero to two-foot conglomerate that occupies channel-cuts in next lower strata. In the basal conglomerate, pebbles are one, rarely 2 inches in diameter, and consist of milky quartz, rarely of quartzite; pebbles or possibly, in part, nodules of somewhat siliceous limestone are moderately common. Base reaches track level at Signal Tower No. 2354.	30	725
Thickness of sandstone member about	65	
Lower shale and sandstone member:		
Thin- to medium-bedded, greenish siltstone, channel-cut at top.	3-6	730
Medium-bedded, cross-bedded sandstone, with solution pits from limy fragments.	7	737
Reddish and some greensih shale, and some greenish sandstone, with 8 feet of greenish sandstone at middle. To 10,746 feet traverse.	18	755
Thickness of lower shaly member	30	

STOP No. 5. Loyalhanna. The Mauch Chunk beds are underlain by the strongly cross-bedded, calcareous sandstones of the Loyalhanna "limestone". The more calcareous parts are somewhat oolitic; sand grains are mostly quartz, commonly rather angular. Butts believes these strata can be traced southward into Fredonia - St. Genevive beds. The rock has been quarried extensively in Pennsylvania for railroad balast.

Exposures are as follows:

Loyalhanna Limestone:		
Thick-bedded calcareous sandstone, weathering with strongly cross-bedded, elevated, brownish sandy bands, enclosing irregular, grayish, calcareous, somewhat oolitic bands or lenses, that weather to deep ruts. To 11,352 feet.	10	765

	Feet
Concealed, the interval represented by strata of the next bluffs. To 11,844 feet.	(765)
Thick-bedded, very strongly cross-bedded, calcareous sandstone, the calcareous bands weathered to deep ruts. Base is 12 feet above track level at 11,844 feet.	35 800
Thickness of Loyalhanna limestone	45

STOPS 6 To 8. Pocono Sandstone. The beds customarily classed as Pocono sandstone or group along the Allegheny Front, consist of the upper, escarpment-making Burgoon sandstone; of a lower-middle complex of sandstones and shales, including some red beds; and of basal sandstones classed as Berea by some geologists.

The Pocono deposits of Pennsylvania undergo important lateral variations in character and in relations to adjacent strata, and present many pboblems that remain difficult to answer.

Willard (1936, 1939) has recently redirected attention to White's excellent exposition of the relations of the Pocono-Catskill beds of northeastern Pennsylvania. It appears that most of the strata of the Pocono Plateau region are late Devonian, and that Pocono strata in the sense used along the Allegheny Front, are to be sought in ridges closely adjacent to the hard coal basins. As so understood, the Pocono at the Lehigh River near Mauch Chunk includes the following divisions according to White; upper, coarse conglomerates and some sandstones, 150 feet; grayish sandstones and some shale, 550 feet; basal, Mt. Pleasant conglomerate, 50 feet, total 750 feet. There are three divisions, somewhat as near Gallitzin and the Horse Shoe Curve, though the sediments are decidedly coarser in texture. Full identity of the apparently corresponding members is, however, made uncertain by the distances separating the several belts of outcrop.

Pocono deposits extend below the surface through almost all of Pennsylvania west of the Allegheny Front. The Big Injun sand of drillers corresponds to the Burgoon sandstone, named from Burgoon Run at the Horse Show Curve; in the Hilliards quadrangle the lower part of the mountain sand is upper Burgoon; parts of the Burgoon are thought to continue into the Logan and possibly the Black Hand sandy beds of central Ohio. The subsurface Squaw and Berea sands of western Pennsylvania correspond to middle to lower parts of the Pocono.

The Pre-Burgoon portion of the Pocono near Gallitzin has been correlated by Butts with the Cuyahoga of Ohio and northwestern Pennsylvania. Laird (1941) believes that lower beds of the Pocono-like sandstones in Chestnut and Laurel Ridges, southwest of Gallitzin, are Pre-Cuyahogan and even Devonian; the effect of such a view on the Horse Shoe Curve section has not yet been clarified.

The Pocono deposits will be examined by three more or less distinct stops as follows:

STOP No. 6. Burgoon Sandstone. The Burgoon sandstone, exposed from 11,844 to 14,538 feet traverse, exhibits the following features:

	Feet	
Pocono Sandstone **Burgoon Sandstone Member**		
Thick-bedded, markedly cross-bedded, in part micaceous, buff- to whitish- and greenish-weathered sandstone. There is some irregularly interbedded greenish shale 15 to 25 feet and 40 to 50 feet below top; shale galls or chips occur at a few horizons, as at 12,275 feet traverse. Butts reports some fossil ferns in these strata. To 13,272 feet traverse	150	950
(Milepost 245 at 12,906 feet)		
Thin-bedded shale, weathered yellowish to greenish, and some interbedded, lenticular, ½- to 1-foot interlayers of sandstone. At 13,272 feet traverse, the next overlying sandstone cuts rapidly into this shale to 13,398 feet traverse.	30	980
Thick-bedded, cross-bedded sandstone, To 13,476 feet.	10	990
Concealed. To 14,166 feet.	120	1110
Medium-bedded, rather fine-grained greenish to buff sandstone. At 14,166 feet, some shale occurs on bank above these sandstones. To 14,538 feet traverse.	55	1165
Thickness of Burgoon sandstone about	365	

STOP No. 7. Sandstone and Shale members of the Pocono; examine near Signal Tower No. 2444 at 15,702 feet traverse. The Burgoon sandstone is underlain east of Gallitzin by over 450 feet of interbedded sandstones and shales, whose deposition was more or less rythemic or cyclic in the following manner.

Scour and Channel Cutting

Deposition of thin-bedded, comparatively regularly-bedded, somewhat silty clays, plausibly in fresh-water to somewhat brankish lagoons or embayments. Plant-fossils common; one body of shale contains pelecypods, fish plates; more definite marine faunas not observed. In a number of the shale bodies, there are red-colored or red-variegated zones.

Deposition of strongly cross-bedded sands, the grains mostly of quartz; whitish micas are common in some of these deposits, and a moderate amount of clayey interstitial matter is commonly present. Some plant fossils; other fossils rare. Plausibly fresh water stream and lagoonel deposits. There is one body of red sandstone 80 to 100 feet above base.

Somewhat similar cycles continue upward into the Burgoon, but there the sand deposits are much thicker both individually and in proportion to the shale; and red-colored beds are lacking.

The reddish sandstone and associated red shale 355 to 390 feet below the base of the Burgoon, may represent the Broad Ford sandstone, reported by Reger (1927) from West Virginia into the Broad Top Basin in Pennsylvania.

Unquestioned marine faunas have not been observed in any of the Pocono strata along the railroad east of Gallitzin. Butts has reported a linguloid brachiopod in a horizon about 300 feet beneath the Burgoon, but the marine versus brackish water significance of the form is not assured. Pelecypods are abundant in shales 195 to 200 feet below the base of the Burgoon as here measured, and one fish plate was discovered; the fauna may well denote brackish waters, but it does not have the positive marine character of the brachiopod of the Riddlesburg shale, 130 to 205 feet beneath the Burgoon at Riddlesburg, 28 miles southeast of Gallitzin (Reger 1927, Girty 1928), or of the brachiopods, pelecypods, and cepholopods that invade many horizons of the Pocono of the Laurel Hill and Chestnut Ridge anticline, beginning near Johnstown 20 miles southwest of Gallitzin. (Laird 1941). In Lairds opinion, the faunas in the 290 feet of Pocono-like sandstones immediately beneath the Loyalhanna at Youghiogheny Gorge in Laurel Hill are Mississippian; he thinks that those in the next lower gray and then some reddish sandstones denote the Late Devonian Conewango series. The faunas are mostly meager and imperfectly preserved, and Laird comments that their evidence must be used with caution. They raise the problem, however: are the middle and lower members of the Pocono east of Gallitzin Devonian and not Mississippian, in the sense that Devono-Mississippian boundary is drawn in northwestern Pennsylvania above the Conewango and below the Oil Lake Series?

In contradiction to such a view, it has been thought by most geologists working in the area that the middle member of the Pocono of the Allegheny Front traces by means of well records into the Mississippian Cuyahoga series of Ohio, the basal sandstone member into the Mississippian Berea sandstone.

The sandstone and shale member of the Pocono includes the following strata, extending from 14,540 to 17,320 feet traverse; examine beds near Signal Tower No. 2444 at 15,700 feet.

Middle sandstone and shale member:	Feet	
Medium-bedded, greenish siltstone, reddish 4 to 5 feet above base. Some plant fossils. to. 14,615 feet.	15	1180
Concealed. to 14,840 feet.	30	1210
(Watchman's house at 14,780 feet.)		
Thin-bedded, silty, somewhat micaceous, greenish-weathered shale, with some reddish variegations in lower half. Plant fossils. To 15,095 feet.	35	1245
Medium- to thick-bedded, strongly cross-bedded, buff to greenish sandstone. To 15,205 feet.	15	1260
Thin-bedded, grayish to greenish shale, with 4 feet of greenish, silty sandstone 60 to 64 feet below top. In the upper third, the shales are dark gray and thin-bedded; below, they are more greenish and micaceous. Topmost 6 inches consist of clay, possibly a regolith. Plants common near base, rarer above. To 15,636 feet.	80	1340

	Feet.	
Medium- to thick bedded, medium-grained, buff to greenish sandstone. To 15,700 feet.	15-20	1360
(Signal Tower No. 2444 at 15,700 feet.)		
Thin-bedded, greenish weathered shale, truncated by next higher sandstone, so that it thins from 15 feet at the Signal Tower to zero in about 150 feet along the bedding. In upper 5 feet: plant fossils (c) small, thin-shelled pelecypods (c); fish scale (r). Base is at track level at 15,755 feet.	15-0	1375
Medium- to thick-bedded, strongly cross-bedded sandstone; some greenish shale 21 to 24 feet below top. To 15,895 feet.	32	1407
Thin-bedded, greenish shale, with a few thin interlayers of sandstone. Some plant fossils. Dip 11° NW. To 16,045 feet.	30	1437
Thick-bedded, strongly cross-bedded, buff to greenish sandstone. To 16,255 feet.	37	1474
Thin-bedded, silty shale, weathered at top and just beneath thin, medium sandstone to yellowish clay (regolithic?). Some small clams. To 16,320 feet.	10	1484
Medium-bedded sandstone, with well-marked channel cutting in lower part. To 16,415 feet.	16	1500
Thin-bedded greenish shale, with some thin interlayers of greenish sandstone, and with 2 feet of red mudrock 5 to 7 feet below top. To 16,520 feet.	22	1522
Reddish silty shale and mudrock, with some thin interlayers of greenish and some reddish sandstone.	15	1537
(Watchman's house at 16,555 feet. Note high escarpment made by Burgoon, south of Sugar Run Valley. There are also fine views to the east and southeast toward Lock, Short and Dunning Mountains with their slides of whitish Tuscarora sandstone of the basal Silurian.)		
Thin- to medium-bedded reddish sandstone and some interbedded reddish shale. This may prove to be the horizon of the Broad Ford of Reger, especially as identified near Riddlesburg. To 16,640 feet.	18	1555
Thin-bedded greenish and some reddish shale, with a few thin interlayers of sandstone. To 16,795 feet.	37	1592

Medium-bedded, greenish sandstone. To 16,910 feet.	21	1613
Thin-bedded, greenish shale, reddish 11 to 16 feet below top. To 17,320 feet.	22	1635
Thickness of middle, sandstone and shale member of Pocono	470	

STOP No. 8. Basal sandstone member of Pocono. The thick-bedded sandstones that have been regarded by Butts and others as marking the base of the Pocono along the Allegheny Front, are finely exposed at 17,320 to 17,850 feet of traverse. It has commonly been thought that this member continues into the subsurface Berea Sand or the Murrysville Sand of the Pittsburgh region, though this correlation cannot be fully substantiated at the present time. The strata are seen as follows.

Basal ("Berea") Sandstone member of Pocono:

Medium- to thick-bedded, strongly cross-bedded, greenish to buff sandstone, tending to break into 2- to 12-inch slabs. To 17,650 feet.	70	1705
Dark red shale, greenish and lumpy (regolithic?) at top. To 17,675 feet.	7	1712
Medium- to thick-bedded, strongly cross-bedded, greenish to buff sandstone. To 17,850 feet.	43	1755
Thickness of basal sandstone member	120	

STOP No. 9. Catskill red beds. The uppermost 80 feet of the Catskill red beds are exposed as the tracks turn toward the northeast, and will be briefly examined; the exposed strata are as follows:

Devonian System:
Catskill red beds:

Thin-bedded, reddish, silty shale and mudrock, with a stronger rib 25 to 31 feet beneath top. At top are 2 feet of greenish clayey shale (regolithic?). To 18,005 feet.	39	1794
Thin-bedded, greenish, silty shale. To 18,035 feet.	9	1803
Medium- to thick-bedded, greenish, fine-grained sandstone. To 18,100 feet.	17	1820
Thin-bedded greenish and some reddish shale. To 18,180 feet	15	1835.

(Milepost 244 at 18,220 feet)

LEAVE TRACKS FOR BUSES AND LUNCH.

Beyond Milepost 244, the tracks turn northeastward and run for a long distance along the strike, without exposures; eventually they turn northwestward, and from 24,588 to 28,110 feet cross the upper part of the Catskill and lower part of the Pocono, reaching the watchman's house at the Horse Shoe Curve at 28,930 feet traverse. INSTEAD OF WALKING from Milepost 244 to the Horse Shoe Curve, take path down mountain side to busses parked on Sugar Run road, and drive to the Curve for lunch.

Busses will drive east on Sugar Run road, crossing Sugar Run at 0.25 miles; Catskill red bed soil and some exposures at 0.3, 0.8 miles, exposed at 1.1 to 1.2 miles. Greenish shale and sandstone of Cheming is loose in cuts at 1.4 to 1.7 miles, same at 2.3 miles.

Road curves sharp left at 2.55 miles near red brick school, and crosses Sugar Run at 2.6 miles. After crossing this bridge bear left. At 3.55 miles turn left and do not cross bridge over Burgoon Run. Cross Run at 4.1 miles and continue to dead end at 4.3 miles, at junction with Burgoon Run road.

Turn left on Burgoon Run road. Red Catskill soil at 5.55 miles, with dam of first of three reservoirs at 5.6 miles. Catskill is finely exposed at 5.7 to 6.0 miles. Turn sharp left at 6.0 miles, crossing dam of a small impounding reservoir. Catskill well exposed at 6.2 to 6.3 miles. Dam of second reservoir at 6.55 miles. Some red beds at 6.7 and 6.8 miles. Dam of third reservoir at 7.2 miles, and Horse Shoe Curve parking space at 7.5 miles

LUNCH

After lunch, climb steps east of small store, to watchman's house at the Curve.

STOP No. 10. Type locality of the Burgoon Sandstone. Here at the sharp bend of the Horse Shoe Curve, heavy beds of the Burgoon sandstone from a high cliff at the nose of Kittanning Point, above the tracks; they correspond to some part of the sandstones seen during the morning at 11,352 to 14,538 feet traverse; they suggest the sandstones at 11,352 to 13,270 feet traverse, and 810 to 950 beneath the top of the Upper Freeport coal, but may belong nearer the base of the Burgoon, estimated at 1165 feet beneath the top of the Upper Freeport coal as seen in the morning trip.

There are fine views at the Curve, of the steep, Burgoon-made escarpment of the Allegheny Front, of the neighboring foothills, and of the three Altoona reservoirs nestling in the Burgoon Run Valley.

The watchman's house at the Curve is located at 28,930 feet traverse along the railroad from the Gallitzin tunnels. The trip is resumed, by walking eastwards along the railroad tracks toward Altoona, continuing downward in the rock succession as follows.

Mississippian:
Basal Burgoon, and Middle and Lower Members
of Pocono Sandstone:

	Feet	
Concealed to 29,866 feet.		
Thin-bedded, greenish-weathered shale, with some 10- to 20-foot bodies of medium- to thick-bedded sandstone. The shaly character of these beds, and the reddish color of the next lower sandstone and shale, are indicative of the middle, sandstone and shale member; hence it appears that these strata belong beneath the Burgoon, at horizons roughly 1150 to 1200 feet beneath the top of the Upper Freeport coal. To 30,240 feet traverse.	100 +	
	55	1200?
(Signal Tower at 30,240 feet.)		
Medium-bedded, dark reddish sandstone and interbedded reddish shale. To 30,352 feet.	20	1220
Concealed. To 32,326 feet	310	1530
(Watering Spouts at 30,556 feet).		
Strongly cross-bedded, dark reddish sandstone, thick-bedded when fresh, but breaking down after weathering into 1- to 3-inch slabs. To 32,458 feet.	20	1550
Concealed. To Milepost 241 at 33,845 feet. Judging from thicknesses of the middle and lower parts of the Pocono-Catskill contact should in a very rough way occur somewhere in the vicinity of Milepost 241.	250	1800+

Devonian System:
Catskill red beds:

Concealed with some reddish shale at 34,146 feet, to 34,146 feet.	80	1880

STOP No. 11. Catskill red beds. For the next mile, to 39,495 feet traverse as measured, the section will cross the great sequence of reddish shales, mudrocks, and sandstones that constitute the Catskill red beds of the Horse Shoe Curve region.

This great mass of material appears to have been deposited under non-marine, deltaic-flood plain, and probably lagoonal conditions. Alternate wetting and aeration in emergent mud flats in the regions of transportation and deposition furthered the iron oxidation begun in the soils of the source regions; and dehydration favored by warmth of climate yielded the hematite that, though small in quantity, is vivid in color.

Studies in New York, in Maryland, and in Pennsylvania have all shown that the red Catskill beds undergo marked lateral changes. The mass of red strata in the east, nearer the old land of Appalachia, interfingers westward with non-red marine deposits, the base of the red deposits becoming progressively younger, and rising from horizons in the Middle Devonian until in northwestern Pennsylvania pinkish beds do not appear until the latest part of the Devonian. A fossiliferous marine tongue penetrating the Catskill of the Horse Shoe Curve area from a still more westerly area, will be examined at 38,860 to 38,930 feet traverse.

The Catskill sequence will be crossed as follows:

	Feet.	
Reddish, somewhat silty shale and mudrock, the latter tending to break into hackly fragments. At top are 2 feet of medium-bedded, bright greenish, fine-grained sandstone, overlain by 3 feet of greenish shale. At 19 feet below top are 2 feet of greenish shale and sandstone, and below this the reddish mudrock has a number of interbedded, 1-inch greenish bands. At 40 to 50 feet below top are thick-bedded, strongly-cross bedded, fine-grained reddish sandstones, the base locally channel cut into the next lower mudrock; there are also irregularities in layering of the shaly parts due to scour and fill. At 81 to 88 feet below top are 7 feet of cross-bedded, greenish sandstone, underlain by 2 feet of greenish sandstone and shale, then by 6 feet of reddish sandstone. Much interbedded reddish sandstone occurs in the lower 25 feet. Dip 13° NW. To 34,830 feet.	155	2035
Thin-bedded, greenish silty shale, with 5 to 10 feet of greenish sandstone at middle. To 35,012 feet.	43	2078
Thick-bedded, solid reddish sandstone, with a few 1- to 3-inch interlayers of reddish siltstone. Dip 12° NW. To 35,152 feet.	32	2110
Concealed. To 35,895 feet.	190	2300
(Signal Tower at 35,180 feet; culvert at 35,510 feet; watering spouts at 35,975 feet.)		
Reddish sandstone and interbedded reddish shale, exposed in cuts adjoining tracks from 36,120 to base. Dip 17° NW. To 36,418 feet.	135	2435
Concealed. To 36,790 feet.	110	2545
Partly concealed, with much reddish shale and siltstone in bank. To 36,990 feet.	28	2573
Thin-bedded, greenish silty sandstone, mostly concealed. To 37,070 feet.	11	2584
Reddish silty shale. To 37,205 feet.	22	2606

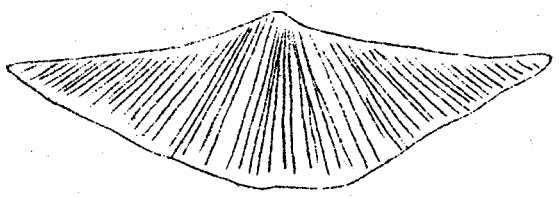
	Feet	
Medium- to thick-bedded, cross-bedded reddish sandstone, partly concealed; there are several thin interbeds of red mudrock, and one 10-foot such bed. To 37,470 feet.	67	2673
Mostly concealed, with red shaly soil. To 37,600 feet.	32	2705
Mostly concealed, but in general consisting of reddish shale and mudrock having some ½- to 1-foot interlayers of reddish sandstone. At 26 to 29 feet below top is greenish sandstone. Some of loose slabs of red sandstone bear ripple marks, generally of symmetrical or oscillation type. To 37,730 feet.	35	2740
Reddish mudrock and thin-bedded red shale, with some 1-foot interlayers of red sandstone, and 23 feet of red sandstone, at 26 to 49 feet below top. Dip 14° NW, 20° NW. To 38,020 feet.	90	2830
Thin-bedded reddish shale varying to hackly, reddish mudrock. A few 2- to 6-inch interlayers of reddish sandstone. To 38,180 feet.	55	2885
Concealed. To 38,860 feet.	270	3155

(Milepost 240 at 38,835 feet is about in line with dam of lowest of three reservoirs.)

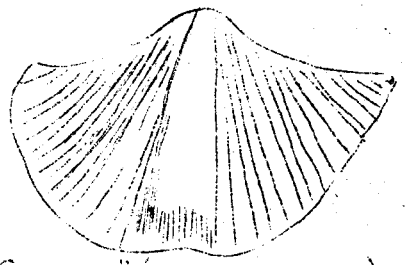
STOP No. 12. Marine tongue in Catskill red beds. Greenish shaly beds, here 250 to 275 feet above base of the Catskill, contain a marine, Chemung fauna, symptomatic of the westward interfingering of the Catskill-type red beds into marine deposits of the Chemung facies.

The fossils occur as follows:

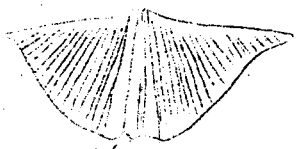
Thin-bedded, greenish shale. Some pelecypods obtained loose in upper part. At 4 feet above base, a 2-inch conglomeratic sandstone contains crinoid rings, Schuchertella chemungensis, Camarotoechia sp., "Spirifer" mesacostalis. This may be the horizon from which Willard (1933) in addition recorded Schizophoria striatula, "Spirifer" disjunctus, Sphenotus contractus. To 38,930 feet.	25	3180
Reddish shale and mudrock, with some sandstone layers in upper part that range to 2 feet in thickness, one at 39,065 feet being 3 feet thick. Some greenish shale and sandstone occurs at 38,990 to 39,005, 39,035 to 39,060, and 39,090 to 39,120 feet traverse. To 39,325 feet.	180	3360
Medium- to thick-bedded, strongly cross-bedded, greenish sandstone. To 39,365 feet.	17	3377
Reddish shale and mudrock, with interlayers of reddish sandstone ranging to a half-foot in thickness. Some greenish shale in basal 10 feet. To 39,495 feet.	53	3430



"SPIRIFER" (CYRTOSPIRIFER) DISJUNCTUS



"SPIRIFER" (PLATYRACHELLA) MESASTRIALIS



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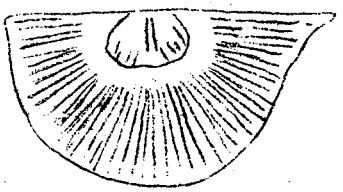
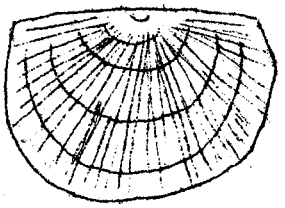
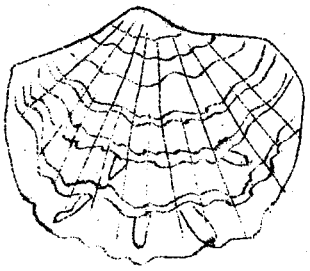


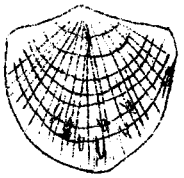
DOUVILLINA CAYUGA



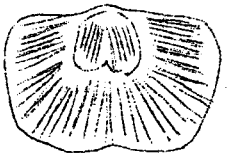
SCHUCHERTELLA CHEMUNGENSIS



ATRYPA HYSTRIX

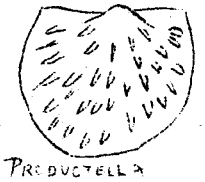


ATRYPA SPINOSA

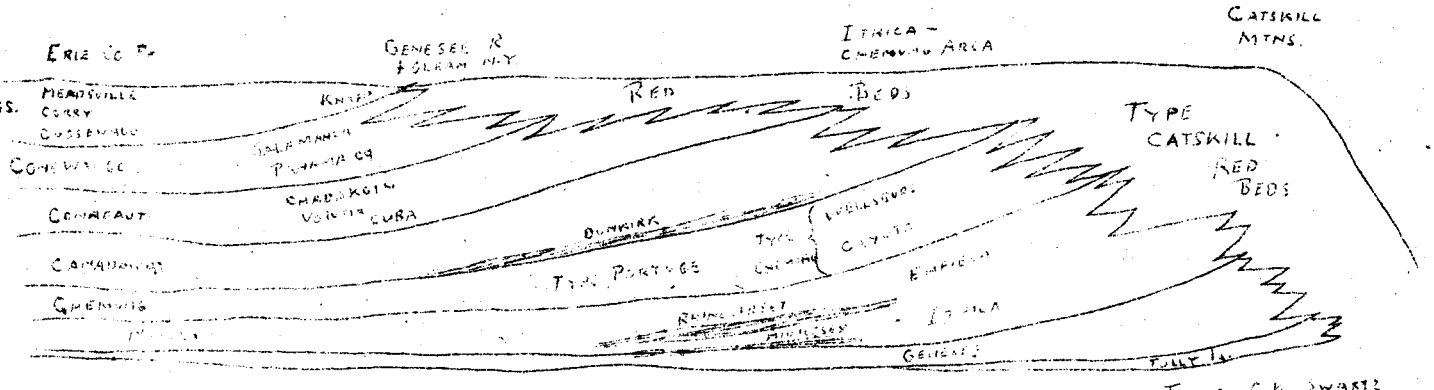


CARNIFERELLA (DALMANELLA) TIOGA

AMBOCOELIA UMBONATA



PRODUCTELLA LACHRYMOSA



FROM C. K. SWARTZ
BASED ON DATA FROM
CHADWICK & CASTER

	Feet	
Thickness of Catskill red beds around	1600-1650	

Chemung Shale:

Thin-bedded, greenish-weathered shale, with 6 feet of greenish sandstone at middle and some sandstone interlayers in lower half. N 19° E, 26 NW Camarotoechia Sp., "Spirifer" of disjunctus, in upper part. To 39,590 feet.	40	3470
Concealed. To 40,410 feet.	360	3830

(Marker 2/1 at 40,400 feet)

STOP No. 13. Upper part of Chemung shale and sandstone. Beneath the Catskill red beds are some 4000 feet of Upper Devonian greenish shales, with 75 feet of fissile, black shales that mark their very base. The upper 2500 feet contain sandstone interlayers that decrease in number below, and possess fossil brachiopod faunas at many horizons; these strata constitute the Chemung. Beneath them, without any well-defined boundary, are greenish shales that are more or less silty but that contain few sandstone interlayers and that are only sparsely fossiliferous; these form the Brallier shale. At the base of the Brallier is a 20-foot body of very fine-grained sandstone, strong enough to crest a line of low foothills. Beneath this in turn are 300 feet of thin-bedded to fissile, gray to somewhat greenish, sparingly fossiliferous beds of the Harrell shale, and these are underlain in turn by 75 feet or so of Burket black shale, at the base of the upper Devonian. The section along the railroad tracks, from 39,495 feet to 45,315 feet traverse extends virtually to the bottom of the Chemung shales; the Brallier, Harrell, and Burket will be seen along the Burgoon Run road and near Endress School after leaving the railroad tracks.

The half mile thickness of the Chemung is characterized in general by the fauna of "Spirifer" disjunctus. Because of relative rapidity of deposition, or comparative slowness of evolution of the animals of the ancient Chemung seas, changes in the fossil faunas do not, as now understood, occur rapidly from horizon to horizon. Nevertheless, significant changes in the fossils can readily be observed in the four successive cuts in which the Chemung will be examined. These modifications are as follows:

First cut, at 40, 410 to 41,060 feet: Greenish and some purplish shales, with numerous sandstone interlayers, and with one 2-foot bed of conglomerate; thickness 270 feet; "Spirifer" disjunctus common at numerous horizons. Coarse-ribbed atrypa hystrix 200 feet below top.

Concealed, 330 feet thickness.

Second cut, 41,885 to 42,360 feet: Greenish shale, sandstone more numerous in upper than in lower half; thickness 260 feet. "Spirifer" meaastrialis near top; "Spirifer" disjunctus rarer.

Concealed. 335 feet thickness.

Third cut 43,029 to 43,449 feet: Greenish shale, some interbedded sandstone

Thickness 225 feet, Douvillina cayuta (c), Spirifer mesacostalis (c), Atrypa sp. between spinosa and hystrix (c), Ambocoelia umbonate (c).

Concealed, 550 feet thickness.

Fourth cut, 44,650 to 45,315 feet traverse. Greenish shale, some interbedded sandstone. Cariniferella troga (c), Douvillina Cayuta (c) Atoypa Spinosa (c), Ambocoelia Umbonata (c).

Of special interest are (1) the abundance of "Spirifer" disjunctus at the first cut, its rarity if not absence at the third and fourth cuts; (2) The change from coarse-ribbed Atrypa hystrix at the first cut to less coarse ribbed Spinosa at the fourth cut; (3) The occurrence at the fourth cut of numerous Cariniferella tioga; this species forms a similar zone of abundance in the lower Chemung in the Cumberland region of Maryland, and furnishes a valuable key for correlations.

The purplish character of parts of the Chemung shales of the first cut is of interest relative to the lateral changes of the Chemung. The purplish color reflects the fact that to the east the sediments of this age are reddish; here at the time of deposition, sediments were being brought in from the reddish mudbanks of the more easterly deltaic-flood plain areas, and on the sea floor the red-colored iron compounds were changing color due to reduction by the organic compounds derived from marine life.

Toward the east, then, first the upper and then lower and lower parts of the Chemung and Brallier of the Horse Shoe Curve area change to red colored sediments. Continuing to the Pocono Plateau region, greenish sandstones and conglomerates interfinger as near source, continental deposits with the red-colored sands and clays of the ancient coastal plains.

The rock succession at Stop No. 13 is as follows:

Thin-bedded greenish shale, and some thin interlayers of greenish sandstone; rock consists of shales with few sandstones 75 to 100 feet below top, and in basal 3 feet. Some of the shales are purplish at 30 to 60 feet below top. Ripple marks at 40,590 feet. "Spirifer" disjunctus occurs in fossiliferous zones at 40,420, 40460, 40,500, and 40,590 feet. To 40,716 feet 108 3938

(Signal Tower at 40,640 feet)

Medium-bedded, conglomeratic sandstone and conglomerate; pebbles mostly are milky quartz, and are $\frac{1}{2}$ inch, rarely $1\frac{1}{2}$ to 2 inches in diameter. 2 3940

Medium-bedded, greenish sandstone and some interbedded shale. To 40,746 feet. 30 3970

	Feet	
Thin-bedded, greenish-weathered and some purplish shale; and much interbedded, greenish sandstone, the thicker layers reaching ½ to 1 foot. Some of sandstones vary locally in thickness due to scour and fill. Symmetrical ripple marks occur at 40,975 feet, and there are prominent nodular structures (compare with "storm rollers") at 40,945 feet. At 40,880 feet, 57 feet below top: "Spirifer" disjunctus (c), Atrypa hystrix (c). N 24° E 30° NW. To 41,060 feet.	130	4100
Thickness of beds, first cut in Chemung	270	
(Tower house at 41,050 feet traverse)		
Concealed. To 41,855 feet.	330	4430
(Underpass for a road at 41,450 feet, Signal Tower No. 2395 at 41,825 feet traverse.)		

STOP No. 14. Second cut in the Chemung beds. Several bodies of fairly strong sandstones occur in the upper portion of the beds in this cut, thinner interbeds in the lower half. In attempting to judge the proportion of the sandstone in the Chemung it must be recognized that the railroad cuts expose the sequence only in the knolls or hills that plausibly represent the stronger part of the formation.

Fine "Spirifer" mesastrialis specimens were obtained 10 feet below the top of the rocks of this cut; the zone can be detected by the holes left where the shells have been removed by leaching.

The rocks at this cut are as follows:

Thin-bedded, greenish shale and some sandstone	5	4435
Medium-bedded greenish sandstone, and a little interbedded shale. "Spirifer" mesacostalis (a) 3½ feet above base.	9	4444
Thin-bedded greenish shale, with several thin sandstone interlayers	24	4468
Thick-bedded greenish sandstone	10	4478
Thin-bedded greenish shale, with curled, sandy layers in upper 5 feet, and 15 feet below top; there are some 2- to 6-inch sandstone interlayers 24 to 30 feet below top.	44	4522
Medium-bedded greenish sandstone with a little shale near top.	11	4533
Thin-bedded greenish shale and some sandstone.	9	4542

	Feet	
Medium-bedded greenish sandstone and some interbedded shale. Sandstone bed 6 to 7½ feet below top is calcareous, with nodular structures and curving layers. In upper 2 feet, at 42,081 feet traverse, are symmetrical ripple marks. "Spirifer" Sp., imperfect, questionably disjunctus, 6 inches below top; Camarotoechia Sp., 2 feet below top. N. 21E., 28 NW.	10	4552
Thin-bedded greenish shale, with some thin sandstone interlayers 20 to 32 feet below top.	48	4600
Thin-bedded greenish sandstone and some shale, forming a fairly prominent rib. Ambocoelia umbonata (a) at base.	3	4603
Thin-bedded greenish shale, with a few thin interlayers of sandstone, the thicker ones, ½- to 1½ feet, at 35, 39, and 44 feet above base. To 42,360 feet.	87	4690
Thickness of beds at second cut in chemung	260	
Concealed. To 43,029 feet.	335	

(Note views to southeast toward Canoe Creek Valley and neighboring Mountains.)

STOP No. 15. Third cut in Chemung shale. Short stops can be made to look for the Chemung fossils abundant in various beds at this cut.

Thin-bedded greenish shale with a few thin sandstone interlayers. Upper 45 feet much concealed.	55	4745
Thin-bedded, laminated greenish sandstone, and interbedded greenish shale predominant 10 to 15 feet above base and half the mass elsewhere. At several layers in upper 5 feet: Douvilline cayuta (c) Productella Sp (c), Atrypa spinosa var. near hystrix (c), "Spririfer" mesacostalis (r), Ambocoelia umbonata (a). Dip 30° NW	22	4767
Thin-bedded greenish shale, with a few 1- to 4-inch sandstone interlayers.	21	4788
Thin-bedded greenish shale, with 3- to 6-inch interlayers of greenish sandstone forming a third to half of mass. At base are some small, faulted flexures. There are nodular structures 15 feet above base, a 1-foot bed of sandstone 25 feet above base. At top, in base of a 1½- to 2-foot sandstone bed are: Bryozoa (a), Douvillina cayuta (r), "Spirifer" mesacostalis (r), Ambocoelia Umbonata.	62	4850
Thin-bedded greenish shale with a few 1- to 2-inch interlayers of greenish sandstone.	44	4894

	Feet	
Thin-bedded greenish shale, containing some 1- to 1½- foot interlayers of greenish sandstone, some with small-scale cross-lamination. N 26 E, 33 NW. At 6 feet below top: Douvillina cayuta (r), Atrypa reticularis (r), "Spirifer" mesacostalis (r) Ambrocoelia Umbonata (c). To 43,449 feet.	21	4915
Thickness of beds at third Chemung cut.	225	
Concealed. To 44,650 feet.	550	5465

(Milepost 239 at 44,435 feet.)

STOP No. 16. Lower Chemung. The fourth cut in the Chemung shales exposes the cariniferella tioga beds lying close to the base of the formation. Sandstone layers are thin though still fairly numerous.

Thin-bedded greenish sandstone, in layers 1- to 6-inches thick, and interbedded greenish shale that forms about a third of the mass.	37	5502
Thin-bedded greenish shale, with a few 1- to 3-inch interlayers of sandstone at 9 feet below top that contain of Schizophoria Striatula (r), Productella Sp. (c), Atrypa reticularis (r).	56	5558
Thin-bedded greenish shale, with some thin-interlayers of sandstone, commonly 1- to 4-inches thick in upper 47 feet, some 6- to 10-inch layers from 47 to 90 feet below top. At 3 feet below top: cariniferella tioga (c), Ambocoelia umbonata (c). 12 feet below top: Ambocoelia Umbonata (a). 17 feet below top: Cariniferella tioga (c), Ambocoelia Umbonata (c), Atrypa Spinosa (r). At 37 feet below top, on underside of an overhanging ledge of a 2-inch sandstone: Douvillina cayuta (r) Cariniferella tioga, fine (c), Atrypa Spinosa (c).	97	5655
Thin-bedded, greenish shale; in basal 1½ feet are two 4- to 7-inch sandstone interlayers, a 6-inch layer at 14½ feet above base, a 2- to 6-inch layer at 49 feet with 1- to 3-inch layers at 39 to 49 feet. At 29 to 30 feet above base: Cariniferella tioga (c), Ambocoelia Umbonata (c).	68	5723
Thin-bedded greenish shale.	20	5743
Thin-bedded greenish shale, with some 1- to 3-inch sandstone interlayers. At 4 feet above base, Productella Sp. To 45,315 feet.	17	5760
Thickness beds in fourth Chemung cut.	295	
Thickness Chemung beds, 39,495 to 45,315 feet. traverse	2330	

BEFORE LEAVING RAILROAD: OBSERVE VIEW TO EAST AND SOUTHEAST. On far side of Canoe Creek Valley, to be crossed in Sunday trip, the basal silurian tuscarora sandstone rises 9 miles to southeast to form Lock Mountain with white rock slides. The entrance to the Valley is constricted on the north by the gently sloping anticlinal nose of Brush Mountain, on the south by the anticlinal nose of Loop Mountain.

In the near foreground, about 2500 feet from the tracks, are low foothills along the outcrop of a 20-foot sandstone at the base of the Brallier. Farther away, at about $1\frac{1}{4}$ mile, is the somewhat higher ridge formed by the Oriskany and Helderberg.

END OF RAILROAD SECTION OF TRIP; LEAVE TRACKS and follow summit of small spur running about S 30 E for about 1000 feet to the Burgoon Run road. Continue east along this road toward Burket Village of the Hollidaysburg sheet. Brallier shales are exposed along the road at about 200 feet from point where road is intersected. The Brallier consists of greenish, somewhat silty shale, with few of the sandstone interlayers of the Chemung, and lacking the numerous fossiliferous zones of that formation. At 2000 feet farther, a 20-foot, very fine-grained greenish sandstone marks the base of the Brallier, and is underlain by the Harrell shale. (N 31 E 50 NW.) Thickness of Brallier is about 1500 feet.

The Harrell is well exposed, in contact with the underlying Burket black shale, just east of the red brick Endress School; continue east about 500 feet from quarry in basal Brallier sandstone; turn right, pass Endress School at 1000 feet. The upper 25 feet of the Burket black shale is exposed just south of the school, directly overlain by the Harrell, 300 feet thick, then by loose blocks of the basal Brallier sandstone. The lower 120 feet of the Harrell are formed of fissile soft gray shale, with some dark gray to black shale 4 to 5 and 15 to 16 feet above base, dark gray shale 81 to 82 and 112 to 115 feet. On the upper 180 feet, some parts of the Harrell become finely silty and are not so fissile as the lower.

TAKE BUS AND RETURN TO HOTEL. If group is highly ambitious, we can stop at Helderberg-Keyser opposite Beth Israel Temple on the way to the hotel.

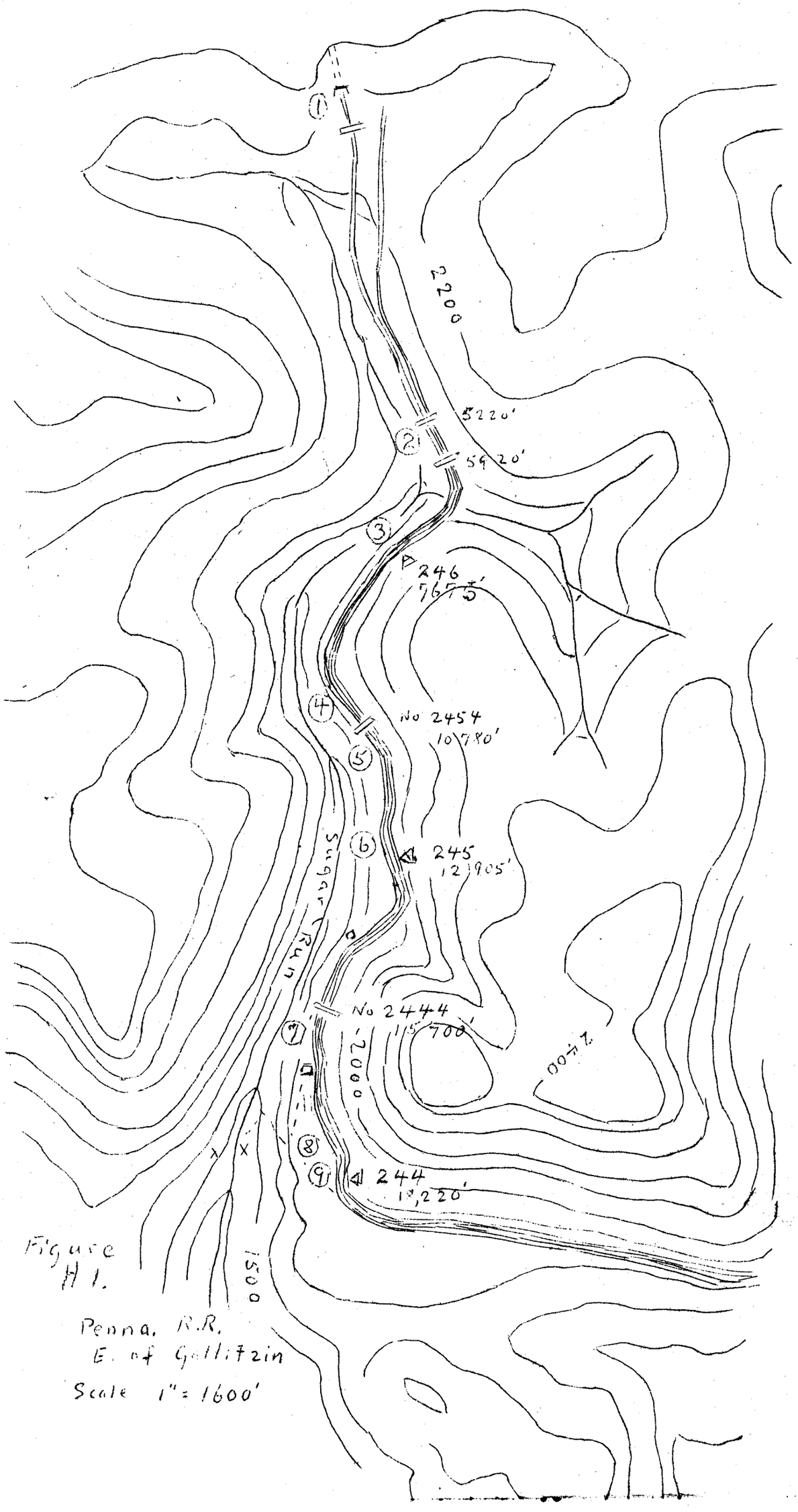
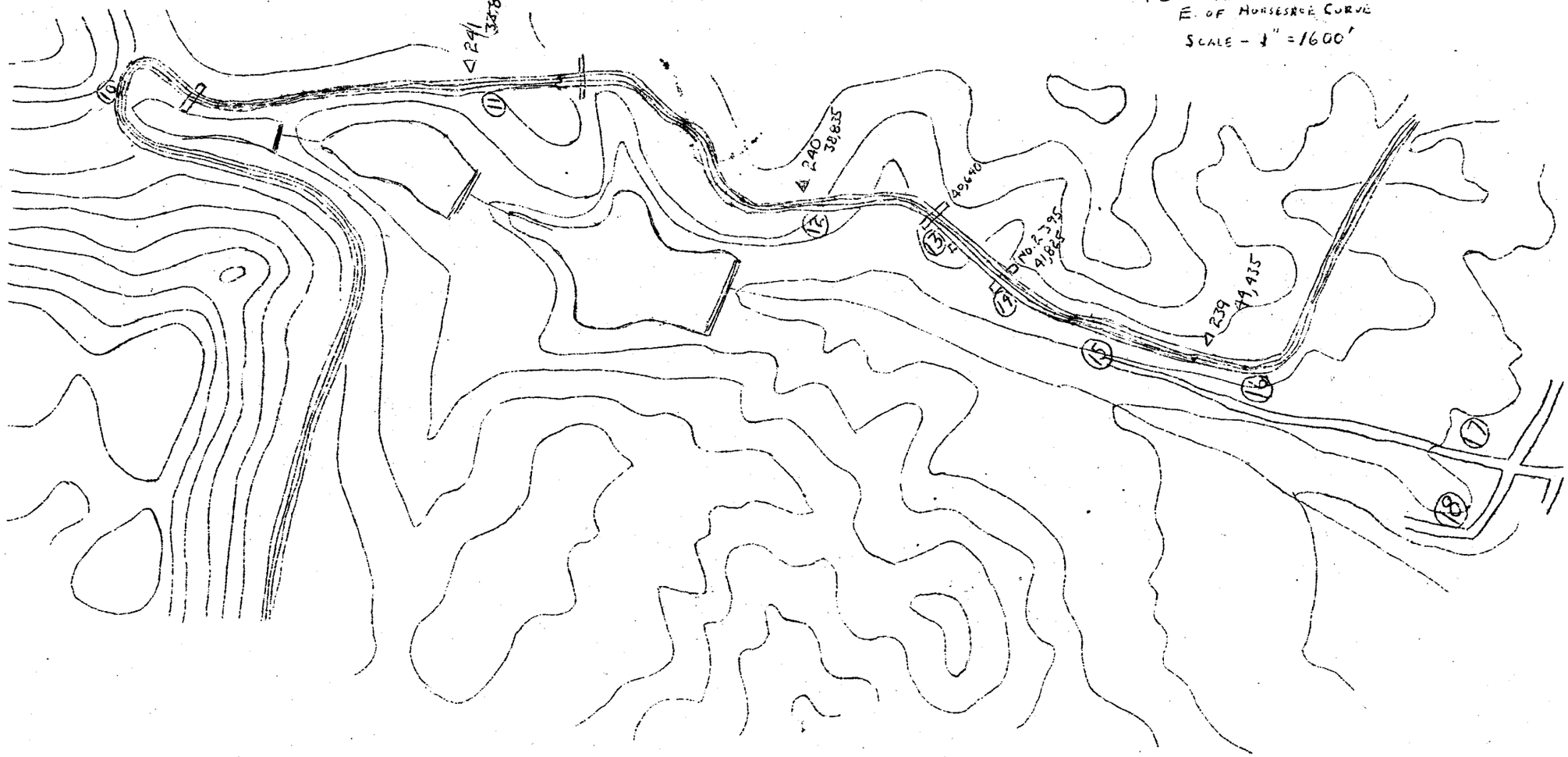


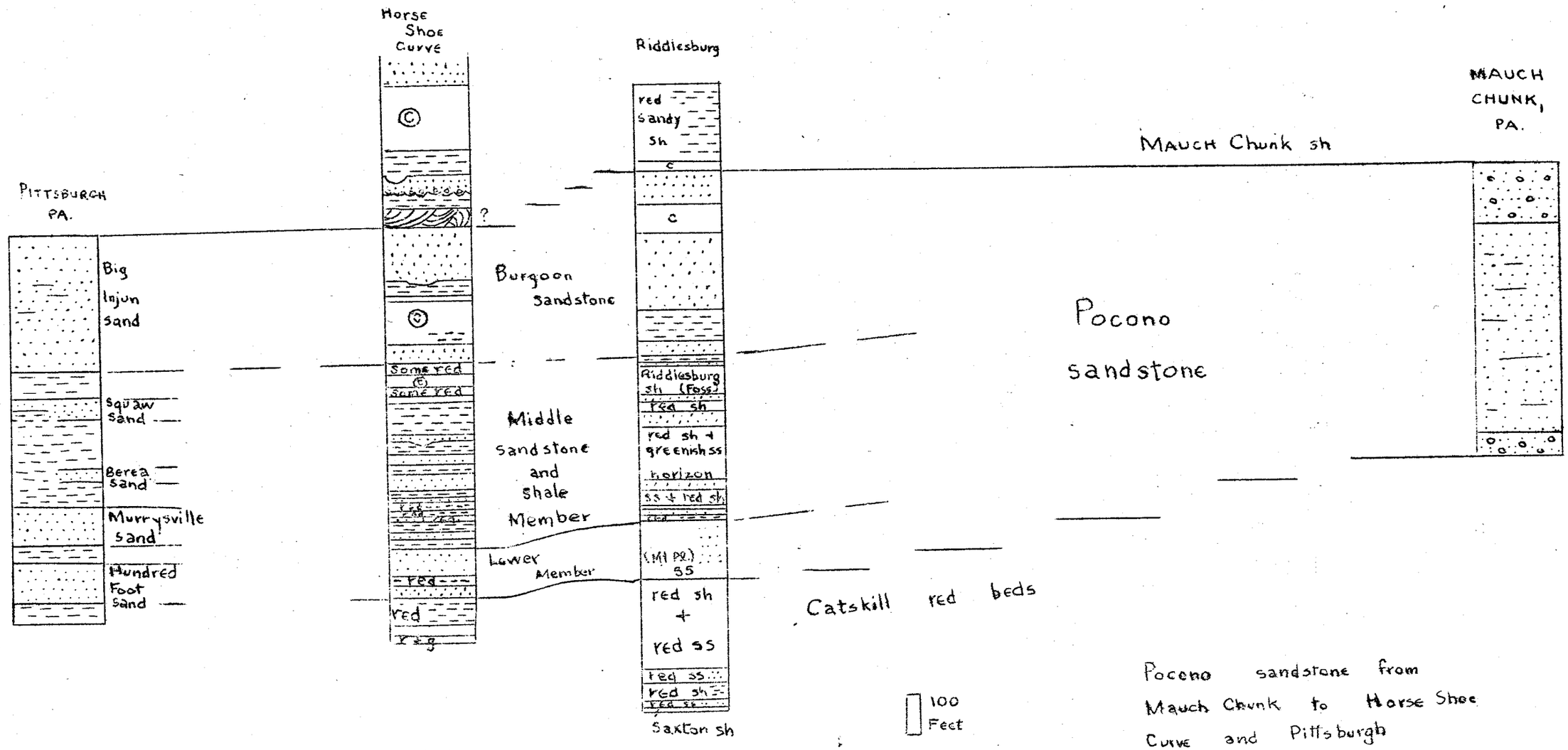
Figure H1.

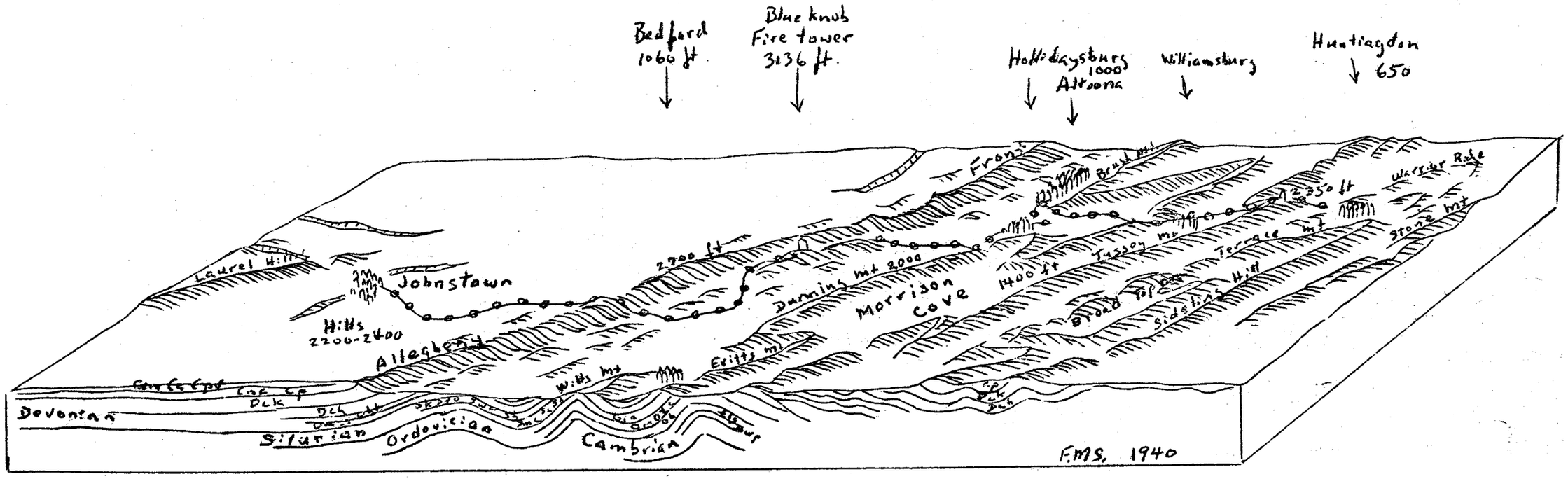
Penna. R.R.
E. of Gallitzin

Scale 1" = 1600'

FIG H-2
PENNSYLVANIA R.R
E. OF HORSESHOE CURVE
SCALE - 1" = 1600'




Horse Shoe Curve
Riddlesburg
MAUCH CHUNK, PA.
MAUCH Chunk sh
PITTSBURGH PA.
Big Injun sand
Squaw sand
Berea sand
Murrysville sand
Hundred Foot sand
Burgoon Sandstone
Middle sandstone and shale Member
Lower Member
Some red
red
red sandy sh
Riddlesburg sh (Foss)
red sh
red sh + greenish ss
horizon
ss + red sh
(Mt Pl.) ss
red sh + red ss
red ss
red sh
red ss
Saxton sh
Pocono sandstone
Catskill red beds
100 Feet
Pocono sandstone from Mauch Chunk to Horse Shoe Curve and Pittsburgh



Block Diagram illustrating geology and physiography between Johnstown and Huntingdon, Pennsylvania

Altoona to Tussey Mountain
East of Williamsburg

Sunday, June 2, 1946

F. M. Swartz

Altoona, Hollidaysburg, Huntingdon, and Tyrone Quadrangles

Southeastward from Altoona, the complex rock upfolds of Nittany Valley and Morrison Cove carry the strata of the Horse Shoe Curve area well above the level of erosion, and expose older strata down to the upper part of the Cambrian System. The generally anticlinal structure of the area is complicated by the doubly rising syncline of Canoe Creek Valley, and by a number of large faults. The Sunday morning trip has been arranged to show parts of the Middle and Lower Devonian of the Upper and Middle Silurian, and of the Ordovician and Upper Cambrian, in relation to the plunging nose of anticlinal Brush Creek Mountain, the syncline of Canoe Creek Valley, the offset fault of Lock Mountain, the strongly faulted anticline of Williamsburg Valley, and an offsetting syncline and anticline of Tussey Mountain. Fine panoramic views are visible from Tussey Mountain if the weather is favorable.

Miles	
	Penn Alto Hotel, Altoona, Pa.; line up on 12th Street.
	Proceed east on 12 th Street
0.15	Turn right on 11th Avenue
0.6	Turn left on 18th Street, go through underpass and follow Route No. 36, which turns left at 1.2 miles, right at 1.4 miles.
2.1	STOP No. 1. Park along route 36 at Beth Israel Temple, and visit section of earliest Devonian and latest Silurian in old quarry bluff across from Temple.

Lower Devonian Helderberg limestones, and Late Silurian Keyser and topmost Tonoloway limestones are exposed, as follows:

Lower Devonian
Helderberg Group

New Scotland limestone: Thin-bedded limestone; lower part somewhat shaly, higher parts contain much dark chert. These beds, though thin, are characterized by the distinctive Eospirifer macropleurus fauna which allows correlations over wide areas. Additional species are Isorthis perelegans, Schuchertella woolworthana, Strophonella punctulifera, Meristella arcucta. 18

Coeymans limestone: Thick-bedded, gray, crystalline, sparingly cherty limestone; upper 2½ feet shaly. Again, the characteristic fauna allows correlation of a very thin body of rock over wide areas. Gypidula coeymanensis abundant. 9½

Silurian System:
Keyser Limestone:

	Feet	
Thin- to thick-bedded limestone, much of it laminated and weathering platy. Some fine "fossil" mudcracks. Contact with Cocymans sharp, plausibly disconformable. Leperditia Sp (aa) 12 feet above base. One-foot bioherms 6 feet above base.	29	94
Stromatoporoid reef-ledge. Thick-bedded, with cabbage-like stromatoporoids. These fossils form reef-beds of great lateral extent in the Keyser limestone.	4	65
Thick-bedded limestone, many stromatoporoides in lower 2 feet.	3½	62
Thin-bedded, black limestone. Leperditia gigantea (a) other Ostracoda.	3	61½
Stromatoporoid reef-bed.	8½	58½
Thin-bedded limestone. Pholidops Sp. (a)	5	50
Thick-bedded gray crystalline limestone. 10 to 20 feet below top, corals are abundant, including Cladopora rectilineata, Halysites.	37½	45
Very nodular, impure limestone, moderately fossiliferous.	7½	7½

Tonoloway limestone

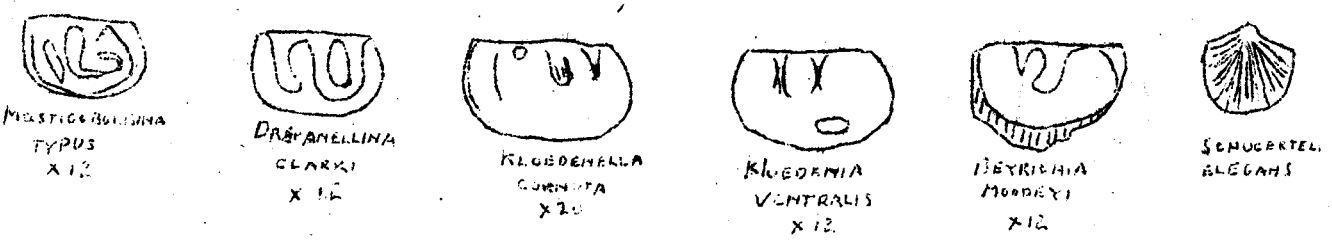
Thick-bedded limestone. Algal (?) fossils	24	
Laminated, dense limestone of typical Tonoloway aspect.	12	
Concealed.		

Return to cars and proceed southeast along Route 36. Tonoloway limestone exposed in bank of creek to left at 2.5 miles. At 2.8 miles, there is a fine view of the gently sloping anticlinal nose of Brush Mountain.

miles	
3.0	Turn right on Route 220-36 (or, to omit stops 2 and 3, go straight ahead to Franklintown.)
3.3	Turn left on Route 220, leaving Route 36.
4.1	STOP No. 2. Park in small clearing on right side of highway near Lakemont Park, to see lower McKenzie and upper Clinton of the middle Silurian.

This section is excellent for study of a number of Middle Silurian faunal zones that are remarkable for their thinnesss and persistence. The rapid change in fossil species may involve several minor disconformities as well as rapid evolution of the animals.

Some of the specially significant species are the following:



The section is as follows:

Middle Silúrian:

McKenzie shale and limestone, lower part:

Thin-bedded dense limestone and interbedded shale, the limestone predominant below; some edgewise conglomerate. Beyrithic moodeyi Zone. 130

Thick-bedded limestone. 5

Dense to finely oolitic limestone and some shale. Whitfieldella marylandica; Kloedenia ventralis. 9

Thin-bedded shale, and interbedded gray sandy limestone. Schuchertella elegans-Kloedenia cornuta fauna; might well be classed as Rochester.

Clinton Group:

Rochester shale:

Thin-bedded greenish shale, with thin interlayers of limestone that contain the Strophcodonta prontyi, Drepanellina clarki fauna. 42

Keefer sandstone:

Calcareous sandstone, weathering ocherous, and some shale; at top, 1 foot of fossiliferous hematitic limestone, the fossils in part replaced by specular hematite. Schuchertella subplana fauna. 15

Rose Hill shale:

Olive to purplish shale, some thin interlayers of coquinite. Three thin beds of oolitic hematite at top. Anoplotheca Sulcata, Mostigobolbina typus fauna. Further down hill are exposures of Middle Rose Hill beds.

Miles

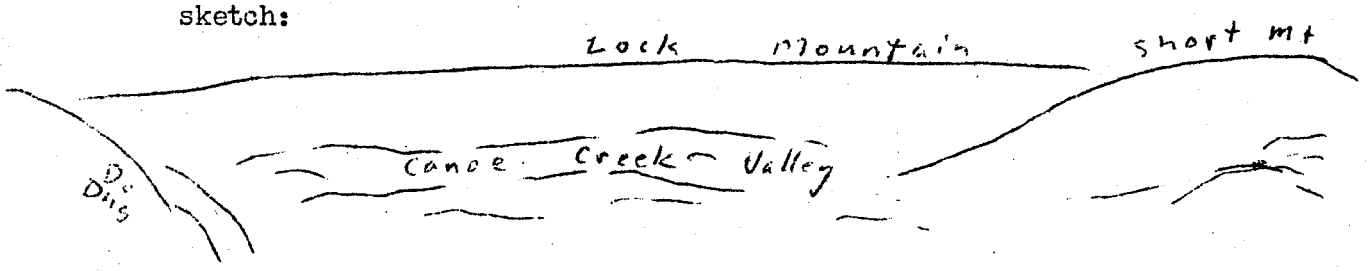
Return to cars and proceed along Route 220 toward Hollidaysburg. Middle Rose Hill beds are exposed along right side of highway at 4.3; at 5.8 miles, old iron ore pits in lower Clinton lie to right about 500 feet from highway, hidden by trees and houses.

6.4 Entering Hollidaysburg.

6.9 Turn left on Route 22.

8.1 to 3 STOP No. 3. Stop at bluff showing fine section of Oriskang, Helderberg, and Upper Tonoloway sediments.

This section lies in the eastern limit of the Brush Mountain anticline, at the entrance to Canoe Creek Valley. The Panoramic view to the southeast and south is suggested by the following sketch:



The Oriskang-Helderberg Section at Stop No. 3 is as follows:

Devonian System:
Marcellus black shale.

Fissile black shale, along old road. 20

Onodago shale and limestone

Calcareous, greenish weathered shale, Thickness reduced by faulting. 10

Oriskang Group;
Ridgeley sandstone:

Thick-bedded calcareous sandstone, "Spirifer" arenosus, Rensselaeria marylanchica fauna; near top, cups of Edriocrinus. 105

Shriver Chert:

Thin- to medium-bedded, dark impure chert or siliceous limestones. Trilobite zone at top. Metaplasia plicata zone near middle. Small faults. 120

	Feet
Helderberg Group:	
Mandata Shale:	
Grayish calcareous shale.	30
New Scotland Limestone:	
Medium-bedded, somewhat cherty limestone; Eospirifer macropleurus fauna.	10
Coeymans Limestone:	
Thick-bedded, crystalline limestone; Gypidula coeymanensis. Small faults.	14
Silurian System:	
Keyser Limestone:	
Medium to thick-bedded, impure limestone, much of it laminated.	43
Medium- to thick-bedded limestone. Spirifer vanuxemi	28
Thin- to medium bedded limestone, with nodules of dark chert.	22
Thick-bedded mostly lumpy limestone. Chonetes jerseyensis Stenoscisura deckerensis fauna.	47
Tonoloway limestone:	
Dense, thinly laminated limestone. Concealed.	100

Return to cars and continue to northeast on Route No. 22. Continue through Frankstown, at 9 to 9.4 miles. (Road from Altoona enters from left at 9.45 miles.)

Miles

9.6 STOP No. 4. Stop to see section of Ridgeley sandstone, overlain by Onondaga shale and Marcellus black shale. This section provides an exceptional display of the Onondaga formation; the Onodaga-Oriskang contact is not fully exposed.

Devonian System:
Marcellus Black Shale:

Fossile black shale.

	Feet	
Onondaga Shale:		
Concealed; some loose greenish shale.	30?	80?
Thin-bedded, greenish-weathered shale, with a few thin interbeds of impure argillaceous limestone in upper 25 feet. Orbiculoidea media, Anoplotheca acutiplicata 20 feet above base.	22	25
Dark, somewhat arenaceous chert. May have resulted from reworking of summit of Oriskang, but Post-Oriskang Age is not fully assured.	1½	3
Concealed.	1½	1½

---Disconformity?---

Oriskang Group
Ridgeley Sandstone:

Thick-bedded, decidedly calcareous sandstone. Uppermost foot is less calcareous, quartzitic, with open joints containing small quartz crystals. Cement is cherty, at least in part. At 9 to 12 feet below top there are many 3- to 4-mm grains; below this the rock is more calcareous and contains more numerous fossils of the Spirifer arenosus fauna.

Return to cars, and continue northeast on Route 22. Go through Geescytown, with low ridge to left made by Oriskany and Helderberg, low ridge to right made by Brallier of Upper Devonian.

Miles	
10.3	Route 22 curves to right.
10.6	STOP No. 5. The upper part of the Hamilton(Mahantango) shale, Burket black shale, and Harrell-Brallier beds are exposed in low cuts along the right bank of the highway.
	Continue east along Route 22, crossing Brallier beds in axial part of Canoe Creek syncline.
12.3	High point on road with fine view of Point View Knob (northwestern corner of Huntingdon sheet.) To north of Point View Knob, Lock Mountain is offset about three-quarters of a mile by an oblique fault; to the south of the Knob, the mountain is cut by the water gap of the Frankstown Branch of the Juniata River; the river has not used the fault line to make its escape from Canoe Creek Valley.
14.1	Cross Canoe Creek near point where it joins Frankstown Branch.
14.8	Highway curves around tip of ridge made by Oriskang-Helderberg Groups.

Miles

15.2 - 15.6 The highway runs directly in line with Lock Mountain where offset north of the Point View fault. Thinly laminated Tonoloway limestone are extensively exposed to left of highway.

15.9 Highway curves to right; greenish mudrocks with some reddish intertongues are well exposed, underlain by Bloomsburg red beds at 16 miles.

16.25 Turn left, following Route 22 up mountain slope. Northern section of Lock Mountain is on left, and red soil of Juniata formation occurs along road banks.

17.2 STOP No. 6. After crossing Township Run at 17.1, park cars at widened part of highway to examine Wills Creek, Bloomsburg, and McKenzie Beds.

The northern portion of Lock Mountain lies to the north, beyond the Point View fault. To the south is the Gap of the Frankstown Branch, to which we will go after examining the section at Stop 6.

The rocks exposed at Stop 6 are early Upper Silurian and late Middle Silurian. They display the intertonguing of the non-red Wills Creek and McKenzie facies with the Bloomsburg red beds, which continues progressively toward the east, until between Harrisburg and the Delaware Water Gap the red beds reach thicknesses of 1500 to 2000 feet, as great or greater than the Catskill near the Horse Shoe Curve. The section here is as follows:

	Miles
Silurian System:	
Wills Creek Shale:	
Laminated, impure limestone and calcareous shale.	100
Thick-bedded, greenish-weathered mudrock, some interbedded laminated limestone and shale. Red shale 11 to 12 and 18 to 22 feet above base.	92
Bloomsburg red beds:	
Thick-bedded red mudrock and siltstone, breaking to hackly fragments	24
Greenish shale above, greenish mudrock below.	11
Thick-bedded red mudrock and siltstone, greenish at 11 to 21 feet.	34
McKenzie shale and limestone:	
Upper Marine Member:	
Greenish, calcareous shale and some limestone	22
Red shale.	6

Feet

Thin-bedded, greenish shale, with limestone interbeds, in part rock in Camarotoedria andrewsi, Homeospira marylandica, Kloedenella gibberosa. Red shale 18 to 21 feet above base. 94

Robble Run red bed member:

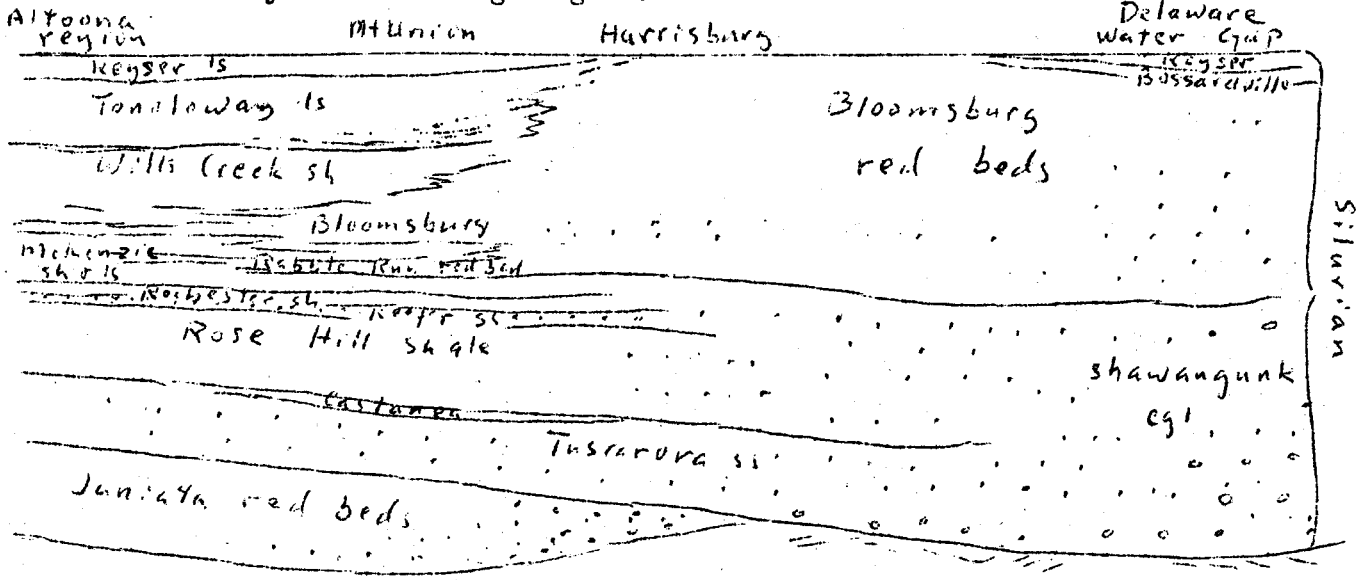
Red shale and mudrock; 8 feet greenish shale in upper part. 45

Lower Marine member:

Greenish shale, with some red interbeds and some thin limestone layers. 63

Concealed.

The relations of these strata to the stratigraphy of Pennsylvania are illustrated by the following diagram:



Turn cars as convenient. Return to bottom of hill, and turn left on highway No. 203 toward Williamsburg.

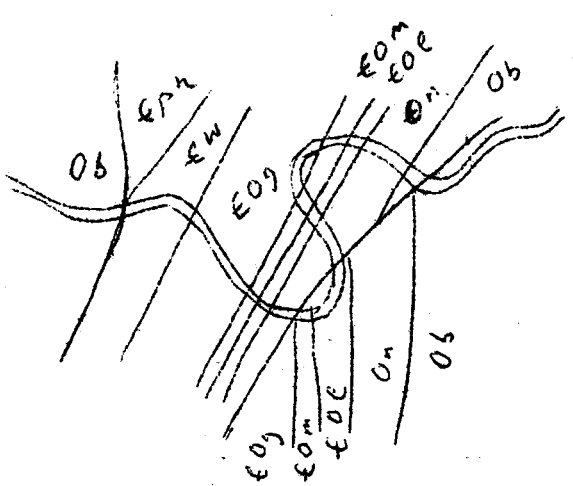
Entering gap of Frankstown Branch, note great talus slides of white Tuscarora; followed by exposures of Juniata red beds and of greenish Bald Eagle (Oswego) sandstone or graywacke. The Reedsville shale is then concealed.

STOP No. 7. Stop near first houses of small village. Along tracks north of highway are exposures of medium- to thin-bedded dense dark Trenton limestone, containing Sowerbyella Sericea and Dinorthis pectinella. To the southeast of the Trenton are large quarries cut into the Black River-Chazy limestones.

Return to cars. Continue toward Williamsburg. Near highway bridge crossing Frankstown Branch, are exposures of topmost beds of Bellefonte dolomite. (Loysburg.) These strata are characteristically dense, laminated, weathering almost whitish.

Continue toward Williamsburg. Bellefonte dolomite exposed along track near crossing. The road curves left and then to right.

STOP No. 8. Stop for review of structure of valley. Across the river are bluffs of early Upper Cambrian, Warrior limestone, with two sandstone beds which weather out in high relief; blocks from these sandstones occur along the roadside. The Warrior limestone is the lowest rock that will be in direct view; though the next lower Pleasant Hill limestone of the Middle Cambrian reaches the surface in this region. The Warrior is at this place brought against the much younger Bellefonte dolomite by the more westerly of two great thrust faults, which extend south for 20 miles and then cut and offset Tussey Mountain. The stratigraphic throw is here about 4000 feet. The structure as mapped here by Batts is as follows:



Ob Bellefonte dol
On Nittany dol
Eol Larke dol
Eom Mines dol
Eog Gatesburg ss & dol
Ew Warrior ls
Eph Pleasant Hill ls

Drive into Williamsburg. One block beyond square turn right and continue to edge of town along road to Beavertown.

STOP No. 9. Stop at edge of town beyond Williamsburg cemetery. The Gatesburg formation is here brought up by the easterly of the two great valley faults. It consists of gray dolomite with interbedded quartzitic sandstone layers; one thin layer of oolitic chert can be seen.

The Gatesburg dips toward the southeast, bringing in the overlying Mines dolomite on the neighboring hill. The Mines lacks the quartzitic layers of the Gatesburg and contains more of the layers of oolitic chert. Walk up private lane leading east on the hill slope south of the cemetery; there is much loose chert, in part oolitic, derived from the Mines which here crops out. Looking northward, the tops of the hills of the valley floor rise to an old erosion surface, presumably the Harrsiburg peneplain. To the northwest and west are Canoe and Lock Mountains, and between them is Point View Knob, cut off between the gap of the Juniata River and the offsetting fault that was previously visited.

Northeastward, at the east edge of Williamsburg, is the prominent scar of a road cut excavated in the Larke and basal part of the Nittany, the latter having in it a moderate number of cherty layers. The separation of the Beekmantown and Nittany dolomites from each other and from the highest Cambrian is more difficult here than to the north, due to the absence of the limestone formations that are present there. The following table compares the Beekmantown and Upper Cambrian sequences near Bellefonte and Williamsburg.

Bellefonte		Williamsburg
	Lower Ordovician or Canadian Beekmantown group	
Bellefonte dolomite, 220 feet		Bellefonte dolomite, 1500
Axemann limestone, 200 feet, Maclurites affinis fauna		(Axemann absent)
Nittany dolomite, 1200 feet Lecanospira rare.		Nittany dolomite, cherty in part, 1200 feet. Lecanospira compacta.
Stonehenge limestone, 600 feet. Bellefontia zone at top.		(Stonehenge absent)
	Upper Cambrian	
(Larke not recognized)		Larke dolomite, chert free, 250 feet.
Mines dolomite, without quartzitic sandstones, with oolitic chert, 250 feet.		Mines dolomite, without quartzitic sandstones, with oolitic chert, 250 feet.
Gatesburg dolomite, with much interbedded quartzitic sandstone, 1700 feet.		Gatesburg dolomite, 1700 feet; upper member with much sandstone the sandstones absent in the lower or Stacey member.
Warrior limestone, about 500 feet exposed.		Warrior limestone, with some thin silty partings, 250 feet.
(Concealed below level of erosion)		Pleasant Hill limestone, argillaceous, 600 feet.
	Middle Cambrian	
		Waynesboro formation, sandstone, red and green shale, 250 feet.

The possibility that the southward disappearance of the limestones may be due to facies changes needs consideration, though it is not supported by the reported reduction in thickness of the Beekmantown deposits.

Return to Williamsburg, and to east on blacktop road to the prominent cut in the Larke and basal Nittany beds.

STOP No. 10. The Larke dolomite and sparingly cherty, basal part of the Nittany are well exposed in the cliffs. Continue east along highway. There are some small exposures in higher parts of the Nittany, extended cuts in the lower Bellefonte. Higher Bellefonte beds are concealed along the highway, but form bluffs along the railroad north of the river. As the road begins to ascend Tussey Mountain, the Chazy, Black River, Trenton, and Reedsville formations are rapidly crossed, with the exposures poor except in the Reedsville. Loose slabs bearing the Orthorhyncula stevensoni fauna of the uppermost Reedsville have been obtained, but are now difficult to discover. The Bald Eagle or Oswego sandstone forms ledges along the roadside where a gap cuts through the northwesterly, subordinate ridge of Tussey Mountain, and a large quarry is being worked in this rock to the right of and below the highway. The highway then turns left, and crosses the Juniata deposits at a small angle to the strike, with a long and gradual rise in elevation, finally reaching the contact with the Tuscarora formation at 2050 feet.

STOP No. 11. Here is a fine view of the mountain scenery of central Pennsylvania. The view is even better from a fire tower reached by a road leading east from the highway. Tussey Mountain is here offset by a minor anticline and syncline, and reappears to the north across the syncline. Tuscarora sandstone crop out at the roadside. For the geomorphology and geology, refer to the accompanying block diagram of the region.

Continue downgrade to the east. There are fine views from various points along the highway.

STOP No. 12. Near bottom of the grade, stop at excellent exposures of fossiliferous upper Rose Hill, Keefer, Rochester, Bloomsburg, and basal Wills Creek. The faunal zones observed at Lakemont at Stop No. 2 are found again at this point.

END OF TRIP. Continue downgrade, at deadend turn left on black top road. Keep left to go to Water Street and points west; take next fork to right to go to Huntingdon and points east.