Edmund M. Spieker

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGY AND MINERAL RESOURCES OF THE BELLEFONTE QUADRANGLE, PENNSYLVANIA

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UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

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W. C. Mendenhall, Director

Bulletin 855

GEOLOGY AND MINERAL RESOURCES

OF THE

BELLEFONTE QUADRANGLE, PENNSYLVANIA

BY

CHARLES BUTTS

AND

ELWOOD S. MOORE

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Edmund M. Spieker

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GEOLOGY AND MINERAL RESOURCES OF THE BELLEFONTE QUADRANGLE, PENNSYLVANIA

By CHARLES BUTTS and ELWOOD S. MOORE[1]

ABSTRACT

The Bellefonte quadrangle is a rectangular area of 230 square miles in Centre County, Pa. It lies mainly within the northwestern part of the Appalachian Valley and Ridge province, known as the "Valley Ridges", but the northwest corner is in the Appalachian Plateau. It is also within the Susquehanna River drainage basin. The most striking feature of the area is Bald Eagle Mountain, which extends in a nearly straight line diagonally northeastward through its middle and rises abruptly 800 to 1,000 feet above the valleys on each side. The Allegheny Front, crossing the northwestern part and rising 800 feet in a bold scarp from its foothills on the southeast, is an almost equally impressive feature as viewed from the southeast. Nittany and Tussey Mountains, in the southeast quarter, rise boldly 900 feet above the wide valley at their northwest base. Nittany Mountain is a synclinal mountain. Northwest of the Allegheny Front is the Appalachian Plateau, of which about 50 square miles lies in this quadrangle, at an altitude of about 2,200 feet above the sea. The elevated margin of the plateau is known as the "Allegheny Mountains." About the southeastern half of the quadrangle is occupied by the great Nittany Valley, with a rolling surface 1,000 to 1,300 feet above the sea. The foothills of the Allegheny Mountains occupy a broad belt of intermediate altitude between the Allegheny Front and Bald Eagle Valley on the southeast. The linear northeast-southwest arrangement of the knobs in this belt is significant, as shown beyond.

Not less striking and significant than Bald Eagle Mountain is Bald Eagle Valley, at its northwest base. This is a perfect and notable example of a subsequent valley developed on a belt of soft rocks. It extends from Lock Haven on the northeast to Altoona on the southwest, a distance of 70 miles. The foothill belt between Bald Eagle Valley and the Allegheny Front is especially characterized by evenly spaced transverse streams with numerous minor lateral streams, giving a perfect example of trellised drainage.

Nittany Valley is drained by Spring Creek, which derives its water mainly from large springs, of which the one at Bellefonte is the largest and gives the town and quadrangle their name. There are a few weak tributaries. The creek is notable from the fact that it is an obsequent stream that has cut its deep gorge through Bald Eagle Mountain and maintained its connection with its master stream at Milesburg.

[1] Begun and partly completed by E. S. Moore and associates at State College, Pa.; later revised and completed by Charles Butts.

The rock formations cropping out in the Bellefonte quadrangle aggregate more than 20,000 feet in thickness. They are all of Paleozoic age, all the systems from Upper Cambrian to Carboniferous (basal Pennsylvanian) being represented. Nittany Valley is underlain by dolomite and limestone of Cambrian to Ordovician age. The Warrior limestone (Upper Cambrian) occupies a narrow area on Buffalo Run south of Waddle, being brought to outcrop on the axis of the Buffalo Run anticline. The Gatesburg formation and Mines dolomite crop out in a wedge-shaped belt 3 miles wide at the southwest corner of the quadrangle and tapering to a point south of Bellefonte. The rest of the limestone and dolomite area is occupied by the thick Beekmantown group, with the higher Ordovician limestones bordering it on both sides. The rest of the quadrangle is occupied by clastic rocks—sandstone and shale—except a narrow belt of Helderberg limestone at the northwest base of Bald Eagle Mountain. The southeast slope of Bald Eagle Mountain is occupied by the Reedsville shale, of Upper Ordovician age. The crest of the mountain is formed by the Oswego sandstone on the southeast and the Juniata formation in the middle, both of Upper Ordovician age, and the main crest is made by the very hard and resistant Tuscarora quartzite, of Silurian age. To the vertical attitude, regular strike, and superior hardness of the Tuscarora and Oswego is due the formation of Bald Eagle Mountain. If the rocks had been limestone or shale there would have been no mountain. Nittany and Tussey Mountains are likewise underlain by the Oswego sandstone. The younger Silurian formations, including the Cayuga group, crop out on the northwest slope of Bald Eagle Mountain, and the Lower Devonian (Helderberg and Oriskany) crop out at its north west base. Bald Eagle Valley is underlain by the Middle Devonian Marcellus shale and Hamilton formation. The foothill belt northwest of Bald Eagle Valley is occupied in succession northwestward by the Upper Devonian Harrell and Brallier shales and by the Chemung and Catskill formations, composed of alternating beds of shale and hard sandstone or conglomerate. The lateral streams have cut shallow ravines in the soft shale and left the harder rocks standing out as knobs arranged in regular lines in a northeast direction, as determined by the general strike of the region. The main scarp of the Allegheny Front and the surface of the Appalachian Plateau are underlain by the Pocono formation, the upper surface of the plateau being made by the relatively resistant Burgoon sandstone member of the Pocono. The Mauch Chunk shale and Pottsville conglomerate occupy only a small knob a few acres in extent near the western boundary of the quadrangle. The eastern margin of the bituminous-coal field lies a few miles west of the northwest boundary of the quadrangle.

The rocks of the dolomite and limestone area in the southeastern part of the quadrangle are rather strongly folded and crossed by anticlines and synclines running in a northeasterly direction. The main axes are the Buffalo Run anticline; the Gatesburg anticline, running across the quadrangle from a point near the southwest corner to a point just south of Bellefonte; and the Penn Valley anticline, in the southeast quarter. These are separated by synclines, the main one of which is the Nittany Mountain syncline. The dip over most of the area southeast of the Buffalo Run axis is generally 15°–40°. Northwest of the Buffalo Run axis to Bald Eagle Mountain the strata dip steeply to the northwest or are practically vertical. In Bald Eagle Valley the dip is about 40° NW., and it decreases through the foothill belt to 5°–10° on the Allegheny Front and Appalachian Plateau.

The Paleozoic history of the Bellefonte quadrangle is inseparable from the history of the Appalachian Valley, of which it is a small part. The history began, according to the latest estimates, as much as 500,000,000 years ago. At that time what is now the eastern United States was part of a vast, nearly level lowland underlain largely by crystalline rocks such as granite, gneiss, and schist. The Paleozoic history began by the subsidence of a wide belt of country extending from Newfoundland to Alabama, coinciding with the present Appalachian Valley. This elongate area was submerged by marine water. Into it was washed sediment from the bordering land by the streams of the time. These sediments compose the quartzite and conglomerate of the oldest Paleozoic rocks now cropping out in South Mountain, Pa., and the Blue Ridge of Virginia. These basal rocks were succeeded by the dolomite and limestone of the formations of Nittany Valley. This deposition was in turn succeeded by a second great deposition of earthy sediment from the lands, forming first the Reedsville shale and then, in turn, the beds of sandstone and shale of the succeeding Upper Ordovician, Silurian, Devonian, and Carboniferous strata now cropping out in Bald Eagle Mountain, Bald Eagle Valley, the foothills of the Allegheny Mountains, and the summit of the Appalachian Plateau. The latest sediments were the coal measures, which extended across the site of Nittany Valley and connected with the coal measures now remaining in the synclines of Broad Top Mountain and those of the anthracite coal fields. During the later Ordovician, all of the Silurian, and all of the Devonian sedimentation vast numbers of marine animals inhabited the sea floor, and their hard parts, or the impressions of them made in the soft sediments, constitute the fossils that abound in those rocks at the present time. During the time of the deposition of the coal measures the valley and plateau areas were occupied by great swamps in which grew the rich vegetation that supplied the vegetal matter now composing the coal beds. Remains of this vegetation are preserved in the impressions of the beautiful leaves of ferns occurring in the shale associated with the coal beds.

During all this immensely long time of Paleozoic deposition the Appalachian belt was slowly sinking, but the rate of sinking must have been slow and the water always relatively shallow, for evidences of shallow water, such as mud cracks, from mud drying in the air, and ripple marks, which can be formed only in water of moderate depth, occur throughout the thickness of the Paleozoic rocks. The deposition of sediment proceeded at even pace with the sinking of the trough and kept it so nearly full that the water was usually of slight depth. From their manner of origin the strata of the sinking trough were naturally about horizontal. At the end of coal-measure deposition a great change began. The Appalachian trough began to rise, instead of sinking as it had been doing throughout Paleozoic time, and, with elevation, the horizontal strata were folded and faulted through lateral compression caused by mighty forces acting from the southeast. Nittany Valley is eroded on the crest of the great Nittany arch, one of the greatest in the world, and the vertical strata of Bald Eagle Mountain occupy its northwest limb. The Birmingham fault is an example of a fault or overthrust that resulted from this compression. This great deformation of the strata is known as the "Appalachian revolution." After this revolution the crust of the earth in the region became quiet, moving neither up nor down, for a very long time, during which the surface was reduced through erosion by running water nearly to a plain (peneplain), lying near the level of the sea. On this plain the streams took their present courses. Spring Creek flowed across the upper edge of the vertical Tuscarora quartzite, which lay at the peneplain level. There was no Bald Eagle Mountain at that time. Later the whole country was again uplifted, but so slowly that Spring Creek was able to wear down its bed through the quartzite as fast as the country rose.

Thus originated the Milesburg water gap. The creek obviously could not have taken its present course if Bald Eagle Mountain had existed. The mountain has come into existence through the erosion of Nittany Valley by Spring Creek, on one side, and of Bald Eagle Valley by Bald Eagle Creek, on the other. The subsequent history of the region has been largely one of topographic development, including the formation of the partial peneplain on the limestone area of Nittany Valley.

The mineral resources of the area are relatively small. Limestone composed of 92 to 98 percent of calcium carbonate is mined at Bellefonte for making chemical lime. It occurs in the Lowville limestone, which crops out all around the margin of the dolomite area of Nittany Valley and will yield a good supply of rock for many years to come. It dips steeply and cannot be quarried to any great depth in open quarries but must ultimately be won by mining, as is now being done at Bellefonte. The other limestone and the dolomite formations yield rock suitable for agricultural lime. A considerable deposit of iron ore (limonite) has been mined out at Scotia. Apparently no other deposits of any size are known. The Tuscarora quartzite elsewhere is utilized for refractory brick and may yield rock suitable for that purpose in this area. A considerable supply of sand can be obtained from the Barrens region on Gatesburg Ridge. Stone for rough masonry could be obtained from several sandstone formations, and perhaps red or brown building stone could be obtained from the Catskill formation. Shale and clay suitable for brick occur in some places.

Adequate water supply is afforded by springs or spring-fed creeks in Nittany Valley and on the foothills of the Allegheny Front. Additional supplies can be obtained from wells of different depths, some as much as 400 to 600 feet.

Nittany Valley has a rich soil derived from the underlying limestone and dolomite, and it is one of the best agricultural regions of the State. Bald Eagle Valley has wide flats of alluvium suitable for farming. The soil of the foothill and plateau country is generally less favorable, but in some places the red soil of the Catskill formation is fairly productive and especially suitable for apple growing.

INTRODUCTION

LOCATION AND AREA

The Bellefonte quadrangle embraces a part of Centre County and includes the geographic center of Pennsylvania. It is named for Bellefonte, the county seat, which derives its name from a beautiful spring in the town. The quadrangle is bounded by parallels 40°45′ and 41° and meridians 77°45′ and 78°. Its location is shown on figure 1. It includes one-sixteenth of a square degree, the area of which in this latitude is 229.8 square miles. It lies in the physiographic division of the United States known as the "Appalachian Highlands" and covers parts of the Appalachian Valley and Ridge province and the Appalachian Plateaus. Brief descriptions of these divisions follow.

APPALACHIAN HIGHLANDS

The Appalachian Highlands include the region extending from the Atlantic Plain on the east to the Interior Plains on the west and from central Alabama on the southwest to northern New York and southern Canada on the northeast. Although the whole area included within the Appalachian Highlands has had a similar geomorphic history and has related geologic features, it contains among others four well-marked divisions—from east to west the Piedmont province, the Blue Ridge province, the Valley and Ridge province, and the Appalachian Plateaus. The Appalachian Highlands and its provinces are shown in figure 2.

Piedmont province.—The Piedmont province is an upland, lying between the eastern base of the Blue Ridge and the Atlantic Coastal

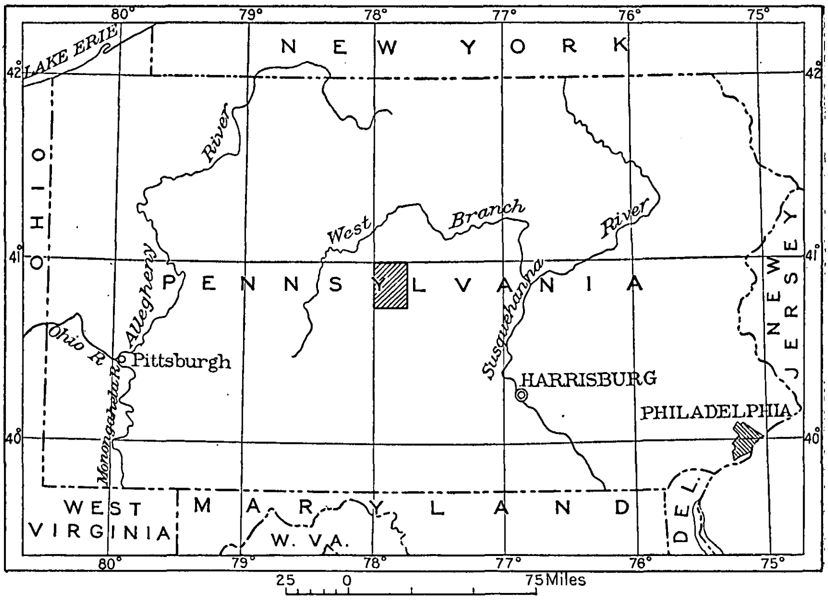


FIGURE 1.—Index map showing the location of the Bellefonte quadrangle, Pennsylvania.

Plain. Extending in a general northeasterly direction from Alabama to New York it has been reduced by erosion to a lower level than the mountains to the west. The boundary between this province and the Coastal Plain is the well-known Fall Line.

The rocks of the province consist chiefly of highly metamorphosed sediments, such as slates, quartzites, and schists, together with igneous rocks, such as granite, diabase and gabbro, which have been largely altered to gneisses and schists.

The altitude of the Piedmont province ranges from about 500 feet in general at the Fall Line to about 1,100 feet at the east side of the Blue Ridge.

Blue Ridge province.—The Blue Ridge province includes a number of ridges and ranges, known by local names, extending from southern Pennsylvania to northern Georgia. The most prominent of these mountains are South Mountain in Pennsylvania, the Blue Ridge and Catoctin Mountain in Maryland and Virginia, the Great Smoky Mountains in Tennessee and North Carolina, and the Cohutta Mountains in Georgia.

The Blue Ridge province reaches its highest altitude in western North Carolina, where the summit of Mount Mitchell, the highest point in the eastern United States, is 6,711 feet above sea level. Southward the height decreases to about 1,500 feet in northern Georgia; northward it decreases to 3,500 feet in the Blue Ridge of central Virginia, 1,500 to 1,800 feet in northern Virginia and Maryland, and

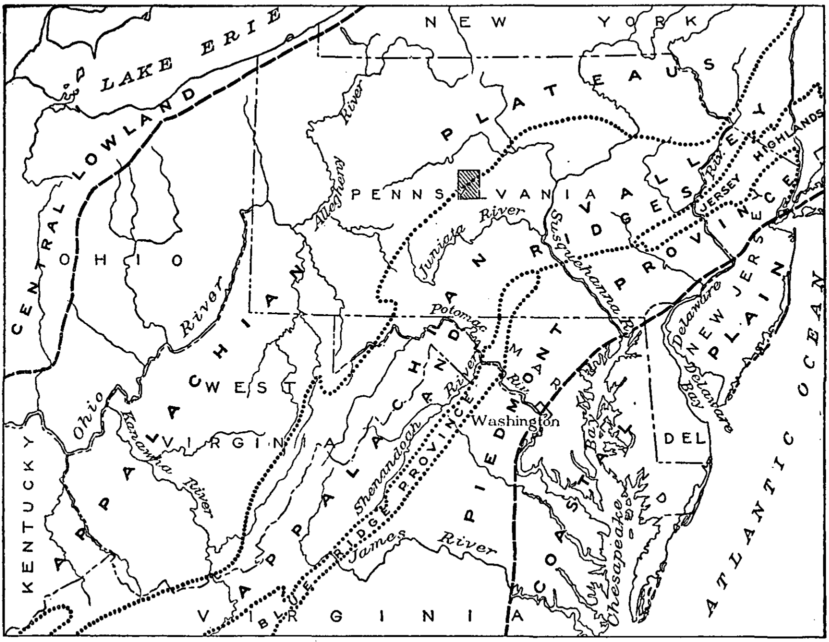


FIGURE 2.—Map showing part of the Appalachian Highlands with its principal subdivisions.

2,000 feet in southern Pennsylvania. This province is underlain by quartzite along the South Mountain of Pennsylvania, by quartzite and schist along the Blue Ridge of Virginia, and mostly by more ancient crystalline rocks—granite, gneiss, and schist, greatly crumpled—in the mountains of western North Carolina and eastern Tennessee.

Valley and Ridge province.[2]—The central division of the Appalachian Highlands is now called the "Valley and Ridge province", as its more striking features are longitudinal valleys and intervening long mountain ranges. However, the central portion of the province is in general lower than the bounding provinces, with respect to which

[2] Although this descriptive designation is appropriate, the authors prefer to use the older and simpler name "Appalachian Valley" in the text of this bulletin.

it is a valley, so that until recently this division has been known as the "Appalachian Valley."

The Appalachian Valley is nearly everywhere sharply separated from the Blue Ridge province on the southeast by a high escarpment and from the Appalachian Plateaus on the northwest by the Allegheny Front, a striking escarpment that crosses central Pennsylvania and continues southwestward as the Cumberland escarpment of Tennessee. The province includes the Shenandoah Valley of Virginia, the Cumberland Valley of Maryland and Pennsylvania, the Lebanon Valley of eastern Pennsylvania, and the Kittatinny Valley of New Jersey. In Georgia, Tennessee, and Virginia this province ranges from 40 to 80 miles in width. It widens to the north and in central Pennsylvania is about 100 miles wide.

The rocks of the Appalachian Valley are almost entirely sedimentary and consist of limestone, shale, and sandstone, 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 rises from less than 500 feet in Alabama to 2,200 feet on the divide between the New and Tennessee Rivers in Virginia and then descends to 2,000 feet in the New River Valley and to 500 feet in the Potomac River Basin. Thence the lowlands rise to a height between 600 and 800 feet in the Cumberland Valley and 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.

Appalachian Plateaus.—The Appalachian Plateaus form the western division of the Appalachian Highlands. They include the Cumberland Plateau of Tennessee and the Allegheny Plateau, which covers the larger portion of western Pennsylvania and New York, most of West Virginia, and small portions of western Maryland and Virginia. To the west the boundary of the plateau is not sharply marked, and some difference of opinion exists as to its proper location.

The strata of this division consists almost entirely of shale and sandstone, which, as they include many coal beds, constitute the coal measures of the eastern United States. They are only gently folded. 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.

Drainage of the Appalachian Highlands.—The Appalachian Highlands are drained partly eastward to the Atlantic and partly southward to the Gulf of Mexico. The Ohio River drains all of the western or plateau division except small areas in Pennsylvania and Alabama. The northern portion of the Blue Ridge all drains eastward to the Atlantic, and the portion lying south of the New River, except the eastern slope, is drained westward by tributaries of the Tennessee River or southward by tributaries of the Coosa River. The northern part of the Allegheny Plateau is drained northward to the Atlantic by way of Lake Ontario and the St. Lawrence River. The main trunk streams (the Susquehanna, Potomac, James, and New Rivers), which generally acquired their courses prior to the development of the present topography, cross the province transversely to the trend of the ridges, through which they have cut deep water gaps. Most of the tributary streams have their origin on the softer strata between the ridges, parallel to which they have eroded deep valleys, which they follow to the main transverse streams. Good examples of these relations may be seen in the Delaware, Susquehanna, and Potomac Rivers and their tributaries. The larger streams flow over the strata almost independently of their structure: they maintain the older courses which they had before the last uplift, when the province was nearer baselevel. (See section on geologic history.)

TOPOGRAPHY

GENERAL FEATURES

The Bellefonte quadrangle contains portions of both the Appalachian Plateau and the Appalachian Valley. These are separated by the Allegheny Front, a steep eastward-facing slope or escarpment 600 to 800 feet high, crossing diagonally the northwest quarter of the quadrangle. The summit of the Allegheny Front is known as the "Allegheny Mountains." The Allegheny Mountains and Bald Eagle Mountain, Nittany Mountain, and Tussey Mountain in the Appalachian Valley are the most prominent features of the topography. The Valley mountains are separated from the Allegheny Mountains and from one another by deep valleys, such as the Bald Eagle, Nittany, and Penn Valleys. In detail the topography of each part of the quadrangle is characteristic of the province to which it belongs, as already briefly described.

RELIEF

The maximum relief within the quadrangle is 1,775 feet—the difference between the highest point, 2,440 feet above sea level, on the Allegheny Mountains, near the western boundary of the quadrangle, and the lowest point, 675 feet above sea level, in Bald Eagle Valley, in the northeast corner of the quadrangle. The second ridge of the Seven Mountains going southward, about three-quarters of a mile south of Galbraith Gap, in the extreme southeast corner of the quadrangle, is 2,430 feet high.

Allegheny Plateau and Allegheny Mountains.—An area of about 25 square miles in the northwest corner of the quadrangle lies in the Allegheny Plateau, where the topographic features are quite different from those southeast of the bounding escarpment. The valleys are usually irregular and head abruptly in narrow gullies. The streams have a dendritic arrangement among irregular hills and spurs, which have a hummocky outline where underlain by shale but steep slopes where capped by sandstone or conglomerate. The Allegheny Front, crowned by the Allegheny Mountains, is the most prominent and striking feature of the region, especially when viewed from the valley to the southeast. This escarpment and the plateau to the northwest of it are capped by resistant sandstone and conglomerate. Locally along the escarpment are large blocks of conglomerate which have become separated from the main masses. (See pl. 12, *A*.)

The topography of the southeastern foothills of the Allegheny Front, extending to Bald Eagle Valley, is marked by deep and approximately even-spaced northwestward-trending valleys separated by broad, dissected spurs gently sloping to the southeast. There is a noticeable linear arrangement of the higher knobs along this belt, caused by the outcropping edges of hard northwestward-dipping strata.

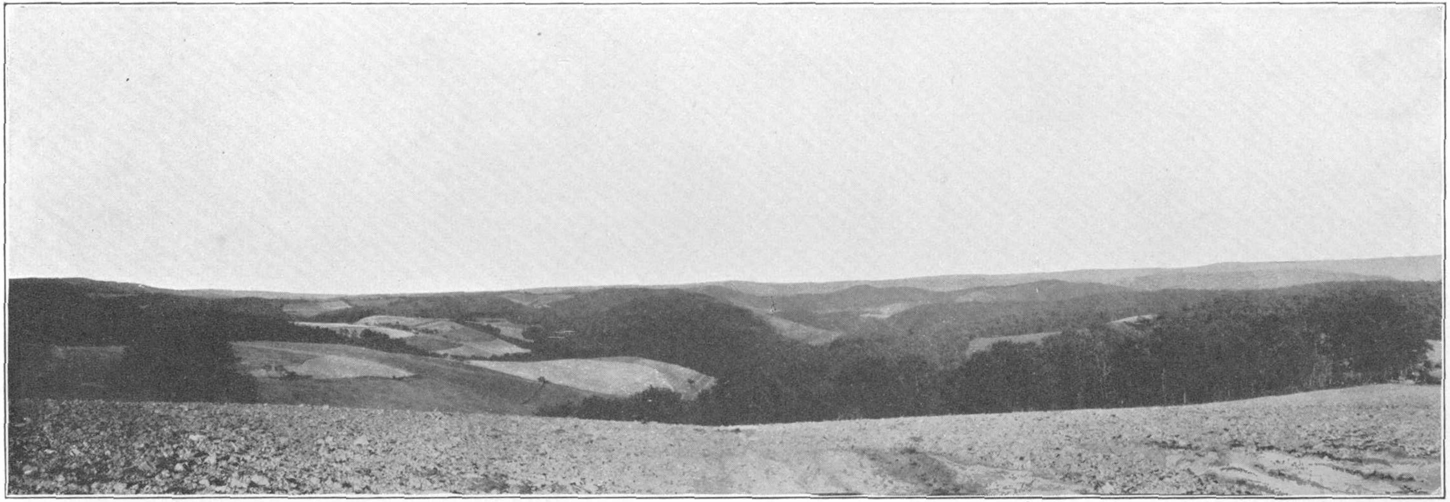
Bald Eagle Mountain.—Bald Eagle Mountain is a sharp, narrow ridge with a double crest made by two formations of vertical resistant sandstone and quartzite, separated by less resistant shale and sandstone. This ridge reaches an altitude of 1,840 feet north of Valley View, in the east-central part of the quadrangle; also near the western border. There is one deep gap through the ridge near Milesburg, at the northeast, but elsewhere the crest is almost unbroken and forms a remarkably even skyline. The high and remarkably uniform northwest slope of the mountain is one of the most striking features of the region.

Nittany Mountain.—Nittany Mountain is a broad synclinal ridge rimmed by two crests, which are 1½ miles apart at the eastern edge of the quadrangle but converge southwestward and unite near Lemont. Between the marginal crests is a shallow depression which is drained westward through McBride Gap, in the eastern escarpment.

Tussey Mountain.—Tussey Mountain, in the southeast corner of the area, is the northern of two ridges of the Seven Mountains that lie chiefly southeast of the Bellefonte quadrangle. The second ridge just enters the extreme southeast corner of the quadrangle. Between these ridges lies a valley eroded in shale and sandstone. The two ridges converge westward into the single Tussey Mountain, uniting half a mile south of the quadrangle and half a mile east of meridian 77°50′, where the northern ridge becomes a conspicuous and persistent shoulder or bench on the northwest slope of the mountain 400 feet below its summit, so that Tussey Mountain in its main extent is strictly homologous with Bald Eagle Mountain. (For further discussion see description of Oswego sandstone, p. 45.)

Nittany, Penn, and Bald Eagle Valleys.—The Nittany Valley extends northeastward from the Juniata River in Huntingdon County, southwest of the Bellefonte quadrangle, to a point about 6 miles east of Salona, in the Lock Haven quadrangle, a distance of 60 miles. Its floor as a whole is gently undulating, but it is characterized by a few features indicative of youthful topography. The ravine known as "Big Hollow" and the valley of Spring Creek, north of Big Hollow, have in places high and precipitous walls. There are a few rather prominent ridges and hills in the valley where it crosses the quadrangle—the Gatesburg Ridge in the southwest corner and a ridge that extends northeast and southwest of Waddle, along the southeast side of Buffalo Run. The highest and lowest altitudes of the Nittany Valley floor, within the quadrangle, are 1,500 and 750 feet above sea level. The Penn Valley merges into the Nittany Valley near Oak Hall and is in fact a branch of it. The Bald Eagle Valley is relatively narrow and straight. It is hemmed in by Bald Eagle Mountain on the southeast and by the foothills of the Allegheny Mountains on the northwest, but it extends continuously from the vicinity of Altoona and Hollidaysburg, southwest of the quadrangle, to the valley of the Susquehanna River near Lock Haven, in the Lock Haven quadrangle. Where it crosses the Bellefonte quadrangle, as well as in its full extent, it is developed chiefly on a belt of shale that crops out at the base of and parallel to Bald Eagle Mountain. Its bottom is flat, and as it is deeply covered with alluvium portions of it form good farming land. It is a perfect example of the linear features of topography developed on steeply dipping soft beds of uniform strike.

Kittatinny peneplain.—The topographic map of the Bellefonte quadrangle shows a remarkable uniformity in altitude in the mountain ridges and peaks, considering the fact that they are capped by rocks that differ in character and geologic age and are folded in



VIEW LOOKING NORTHEAST FROM A BENCH ON THE FOOTHILLS OF THE ALLEGHENY FRONT NORTHWEST OF BELLEFONTE AT AN ALTITUDE OF ABOUT 1,635 FEET.

Crests of Bald Eagle and Nittany Mountains in the extreme distance. Possibly remnant of Schooley peneplain. Photograph by Charles Butts.

different degrees. In the southeast corner of the quadrangle an unnamed ridge composed of quartzite reaches an altitude of 2,430 feet. Bald Knob of Tussey Mountain is composed of sandstone and conglomerate and is 2,300 feet high. Nittany Mountain rises to 2,100 feet, and many of the peaks in Bald Eagle Ridge range in altitude from 1,700 to 1,840 feet. The highest points in the Allegheny Mountains are 2,440 feet above sea level.

The generally slight differences in altitude just noted are such as might be expected on an old erosion surface, which, though worn down nearly to a plain, has not actually been made level. The approximately uniform tops of the ridges in this area thus appear to represent remnants of such an old erosion surface or peneplain, which may correspond to the Kittatinny peneplain, named from the Kittatinny Mountains of New Jersey and represented at many localities south and east of this quadrangle. At the time of its completion this peneplain stood near the level of the sea. It was subsequently elevated to the level of the present summits, and the present valleys have been eroded in the shale and limestone, leaving the more resistant strata in relief as the ridges and mountains.

Schooley peneplain.—The foothills of the Allegheny Mountains, 1,500 to 1,600 feet in altitude, represent apparently a second old erosion surface, possibly corresponding to the Schooley peneplain, named from Schooley Mountain, also in New Jersey. (See pl. 4.)

Harrisburg peneplain.—The broad and approximately flat-bottomed Nittany Valley, underlain by several different formations, represents a still younger erosion surface that may be the same as the Harrisburg peneplain, which is much better developed near Harrisburg. Spring Creek and Logan Branch have lately deepened their valleys, perhaps because of general uplift of the region, and may therefore be called "rejuvenated streams," entrenched in this plain, but the lowering of the gap through Bald Eagle Mountain by other causes might also account for their rejuvenation or recent downcutting.

DRAINAGE

The largest stream in the quadrangle, Bald Eagle Creek, rises a short distance northeast of Tyrone and enters the West Branch of the Susquehanna River near Lock Haven. It is joined by many small streams from the Allegheny foothills and escarpment to the northwest, but Spring Creek is the only large tributary from the south within the quadrangle. This creek, which is joined by Buffalo Run and Logan Branch, has cut a deep gap through Bald Eagle Mountain between Bellefonte and Milesburg, and it now drains practically all the quadrangle south of that ridge, only a small amount of the drainage flowing southwestward. Beech Creek rises in the northwestern part of the area, flows northward a short distance, swings toward the east, and joins Bald Eagle Creek at the town of Beech Creek, 15 miles east-northeast of Milesburg. A small part of the northwestern area is drained by Benner, Rock, Dry, and Pine Runs into Black Moshannon Creek, northwest of the Bellefonte quadrangle, and thence into Moshannon Creek, which in turn empties into the West Branch of the Susquehanna River. Most of these streams originate in the numerous springs in the highlands.

The underground circulation in the limestone and dolomite areas is very extensive, and sink holes are common. A striking example of subterranean drainage is afforded by Big Hollow, a distinct stream channel now usually dry. Its drainage probably issues in the large spring farther down the valley near a spot known as "Rock." The stream issuing from McBride Gap plunges from view half a mile below and is supposed to reappear in the springs near Pleasant Gap Station. Buffalo Run apparently carries only part of the drainage from the southeast flank of Bald Eagle Mountain. The rest may issue from its underground course in the large spring at Bellefonte.

The nearly even spacing of the southeastward-flowing streams in the eastern foothills of the Allegheny Mountains and of the numerous minor lateral streams at right angles to the main streams is worthy of notice. The same feature on a smaller scale marks the southeast slope of Bald Eagle Mountain. Such a drainage pattern is named "trellised drainage" for obvious reasons. It is explained under the heading "Geologic history" (pp. 83–96).

GENERAL GEOLOGY

STRATIGRAPHY

AGE OF THE ROCKS

The rocks of the Bellefonte quadrangle are all of sedimentary origin. They range in age from Upper Cambrian to Pennsylvanian and include a remarkably complete column of Paleozoic strata. The oldest outcropping formation, the Upper Cambrian Warrior limestone, is exposed only on the crest of the Nittany Valley anticline; the Silurian is exposed along the northwest side of Bald Eagle Mountain and on the second ridge of Tussey Mountain; and the Pennsylvanian on the highest level of the Allegheny Mountains. The remainder of the quadrangle is occupied by the younger Cambrian,[3] Ordovician, Devonian, and Mississippian formations, which are well developed, the first three being of great thickness.

The valleys immediately adjacent to the streams are covered with alluvium, and the mountain sides with talus (soil and boulders), so that there are but few exposures of some of the formations. For

[3] See statement of the view of Mr. Butts under heading "Cambrian system," p. 13; also discussion, pp. 19–20.

that reason it has not been possible to acquire as full a knowledge as is desirable of the character and boundaries of some of the formations in parts of the quadrangle.

The areal distribution of the formation is shown on plate 1, and the structure on plate 2. The sequence, character, and thickness of these formations are shown in the columnar section (pl. 3).

CAMBRIAN SYSTEM

The Cambrian system is represented in this quadrangle by four formations—the Warrior limestone, Gatesburg formation, Mines dolomite, and Larke dolomite—all of Upper Cambrian age. The Gatesburg, Mines, and Larke formations are assigned by Ulrich to his Ozarkian system, an assignment fully accepted by Mr. Butts.

WARRIOR LIMESTONE

Character and thickness.—The Warrior limestone, named by Butts[4] 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.

A very satisfactory section of this formation was measured north-northwest of Scotia at exposures on the outcrop southeast of the axis of the Nittany anticline.

Section of Warrior limestone north-northwest of Scotia

	Feet
Sandy soil, of Gatesburg formation.	
Dense blue to gray limestone, with a number of brittle, reef-like beds of *Cryptozoon undulatum* Bassler. This fossil is common in the upper beds of the formation	202
Dense blue limestone with thin beds of gray partly sandy shale. Contains many wavy clay partings between limestone beds, some of which are distinctly lens-shaped and contain *Cryptozoon undulatum* Bassler. Also contains beds of edgewise conglomerate, commonly associated with compact limestone which is spotted red and contains trilobite fragments	176
Limestone containing large oolite grains and fragments of trilobites	4
Dense thick- to thin-bedded dark-blue or grayish-black limestone with shaly partings and layers in lenses of edgewise conglomerate	164
Bed of oolitic limestone	2
Dark impure and grayish-black shaly limestone	140
	688

[4] Butts, Charles, Geologic section of Blair and Huntingdon Counties, central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 46, pp. 523–537, 1918. The thickness 250 feet given in the section on p. 537 is a misprint for 1,250 feet.

The thickness of the section measured is probably not the full thickness of the Warrior limestone, for there is no evidence that the section extends to the bottom of the formation. In the vicinity of Williamsburg, 25 miles southwest of Scotia, the thickness as determined by Butts is about 1,200 feet.

This section is typical of the formation. The upper *Cryptozoon*-bearing bed is persistent. Beds of edgewise conglomerate and reddish limestone conglomerate are also common. Beds of oolitic limestone, carrying fragmentary trilobites, occur in the hill half a mile southeast of Waddle and also southeast of Mattern Junction, as well as in the area where the foregoing section was measured.

The thick beds of bluish limestone are burned on a small scale for agricultural lime, and small deposits of iron ore occur in places on the outcrop of some of the shaly beds.

Distribution and surface form.—A long, narrow area on the crest of the Nittany anticline extending from the vicinity of Waddle to a point 2 miles west of Scotia is occupied by the Warrior limestone.

Fossils and correlation.—The fauna of the Warrior limestone consists mainly of trilobites, which are fairly plentiful in some layers; brachiopods, of which there are very few kinds and individuals; and one or two species of Cryptozoa. Only *Cryptozoon undulatum* Bassler and the trilobite *Millardia avitas* Walcott have been described. Preliminary examinations of the trilobites by Walcott and Ulrich have resulted in an estimate of 15 to 20 genera. Some of these are provisionally referred to or compared with such published genera as *Blountia*, *Lonchocephalus*, *Kingstonia*, *Modocia*, *Plethopeltis*, *Ptychoparia*, and *Ucebia*. The peculiar fossil *Pemphigaspis* cf. *P. bullata* Hall also occurs. One of the brachiopods has been compared to *Micromitra*.

This fauna in its present stage of investigation does not afford adequate evidence for exact correlation. It is recognized as of Upper Cambrian age. The genus *Millardia* is represented by *M. optata* (Hall) and the genus *Pemphigaspis* by *P. bullata* Hall in the Eau-claire formation near the base of the Upper Cambrian in Wisconsin, and the genera *Blountia* and *Kingstonia*, though they have been referred to the Maryville limestone of eastern Tennessee, actually occur in the Nolichucky shale. The upper half of the Warrior limestone carrying these fossils is therefore provisionally correlated with the lower part of the Upper Cambrian of Wisconsin and with the Nolichucky shale of the southern Appalachians. The Upper Cambrian age of the Warrior limestone is also attested by the occurrence immediately beneath it in the vicinities of Henrietta and Williamsburg, Blair County, Pa., of a limestone carrying such Middle Cambrian genera as *Neolenus* and *Acrocephalites*. About 1½ miles due north of Henrietta, also, the Middle Cambrian beds rest upon beds carrying *Olenellus*, *Bonnia?*, and *Hyolithes*, all probably of Lower Cambrian age. At Henrietta and near Williamsburg also the Warrior limestone is immediately overlain by the Gatesburg formation, as it is in the Bellefonte quadrangle. The full sequence crops out in descending order, dipping southward, in the narrow ridge extending about 3 miles north of Henrietta, as shown on the map of the Hollidaysburg quadrangle. It is probable that the same sequence exists in the Bellefonte quadrangle through the Gatesburg and Warrior to the Lower Cambrian.

HIATUS BETWEEN WARRIOR LIMESTONE AND GATESBURG FORMATION

The upper formations of the Upper Cambrian as defined in Wisconsin are absent in central Pennsylvania, and there is a hiatus of considerable magnitude between the Warrior limestone and the overlying Gatesburg formation.

GATESBURG FORMATION

Character and thickness.—The Gatesburg formation was named from Gatesburg Ridge, in the southwestern part of the quadrangle. The name was proposed by E. S. Moore but was first published by Butts.[5] The formation consists of a series of interbedded dolomite, dolomitic limestone, shaly dolomite, and sandstone. It is predominantly dolomitic and sandy, whereas the Warrior is chiefly limestone, much of which is comparatively pure.

As the Gatesburg is very little exposed in the Bellefonte quadrangle, its real character must be made out from the well-exposed section along the Pennsylvania Railroad in the vicinity of Birmingham, Huntingdon County, where it is composed of alternating deposits of sandstone and dolomite in the proportion of about 1 to 10. The dolomite is both thick- and thin-bedded, in large part coarsely crystalline, and dark steely bluish. The lower part of the formation includes a good thickness of thin-bedded dolomite or magnesian limestone with a few thin layers of sandstone, as can be seen southwest of the fault in the railroad cut next southeast of Birmingham station. There are are also many streaks of limestone conglomerate, and a few thin streaks of oolitic rock. Peculiar gashes appear on the surface of the thick-bedded dolomite, a feature common in dolomites. These gashes are possibly due to cracks formed on mud flats. The dis-

[5] Butts, Charles, op. cit., pp. 527–538.

tinguishing character of the Gatesburg is its pure sandstone or quartzite, which occurs throughout the formation in beds as much as 10 feet thick, intercalated in the dolomite. The cement is generally calcite or dolomite, and the rock weathers readily. Less commonly the cement may consist of silica, changing the sandstone to quartzite, or of iron oxide, so that the rock resists disintegration.

On weathering, most of the sandstone disintegrates to sand, but some remains as boulders, and such material so completely mantles the surface underlain by the Gatesburg as to suggest that the underlying rock is composed of sandstone only, whereas sandstone probably does not make up more than 20 percent of the whole and perhaps less than that. A trip across The Barrens, in the southwest quarter of the quadrangle, will reveal the truth of the above statement. In places in the region sand accumulates to such depth that it is a source of building sand. The grains of sand are rounded, the smaller ones commonly more perfectly than the larger ones. Clay also results from the disintegration of the Gatesburg, and in places deep accumulations of mixed clay, sand, and fragments of sandstone include considerable deposits of iron ore (limonite), which have been worked at Scotia, in the Bellefonte quadrangle, and at Ore Hill and the old town of Mines, in Blair County, southwest of the quadrangle.

Owing to the poor exposures of the Gatesburg, a reliable determination of the thickness is not obtainable in this quadrangle. On the railroad southeast of Birmingham, where, however, the bottom is not exposed, the width of outcrop is about 4,000 feet and the average dip is 23° SE., giving a thickness of 1,600 feet. In the vicinity of Drab, Blair County, 6 miles southwest of Williamsburg, where the strata are vertical, the Gatesburg is 1,750 feet thick. It is probably not less than 1,600 feet thick in the Bellefonte quadrangle.

Distribution and surface form.—The Gatesburg formation occupies the central portion of the Nittany Valley, extending northeastward as a broad belt from the southwest corner of the quadrangle to Spring Creek 2 miles south of Bellefonte, where the gentle northeast pitch of the Nittany arch carries it below the surface. There is another area just east of the Pine Hall fault in the southern part of the quadrangle. The surface underlain by the Gatesburg is rolling and is covered with numerous blocks of sandstone, limonite, and dolomite. The soil of the Gatesburg formation is very sandy and on the whole barren, except where material washed from slopes has accumulated. Most of the area of the formation is covered by a forest of scrub oak and is known as "The Barrens."

Fossils and correlation.—No fossils have been found in the Gatesburg formation in the Bellefonte quadrangle except traces of

Cryptozoon, which occur in the central portion of the formation. A large suite of trilobites has, however, been obtained from the Ore Hill limestone member in the middle of the Gatesburg in the Huntingdon and Hollidaysburg region. Studies of these forms have not been completed, and their significance for correlation has not yet been established. Further discussion of correlation is given under the Mines dolomite (p. 18).

MINES DOLOMITE

Character and thickness.—The Mines dolomite was named by Butts after the small village of Mines, in the western part of the Hollidaysburg quadrangle, in Blair County. The appearance of the Mines dolomite in the upward sequence of the formations is marked by the almost complete absence of sandstone and the occurrence of an abundance of oolitic chert, of which there is very little in the Gatesburg. Otherwise, there is no marked difference between the two formations, and in places there is much uncertainty as to the location of the boundary between them.

The Mines dolomite consists predominantly of coarse-grained light to very dark gray dolomite. The dark beds, which occur mostly in the upper 50 feet of the formation, are commonly oolitic and contain considerable bituminous matter. When the rock is struck with the hammer it emits a disagreeable odor somewhat resembling that of hydrogen sulphide. Near the old Nittany furnace, just south of Bellefonte, the dolomite shows on some beds a peculiar corrugated surface, due to weathering. Most of the depressions in this surface are partly filled with chert. Many of the dolomite beds contain sand grains in varying proportions, and in a few thin layers perhaps the proportion of sand is so great that they may be classed as sandstone. An abundance of silica in the form of chert also characterizes this formation, much of it replacing the originally calcareous heads or layers of *Cryptozoon*. Such silicified heads or masses of all sizes make a considerable part of the chert debris on the outcrop of the formation. Calcareous bodies similar to *Cryptozoon*, made by living calcareous algae along Conestoga Creek in Lancaster County, have been described by Roddy.[6] Much of the chert scattered over the surface of the Mines outcrop is oolitic—that is, it is composed largely of little black spherules embedded in a groundmass of light-colored silica. (See pl. 5, *A*.) Such chert is derived from distinct layers as much as 20 inches thick, scattered through the main body of the Mines. The oolitic grains were origi-

[6] Roddy, H. J., Concretions in streams formed by the agency of blue-green algae and related plants: Am. Philos. Soc. Proc., vol. 54, pp. 246–258, 1915.

nally composed of calcium carbonate, which has been replaced by silica in the course of weathering. The oolitic grains of the Mines are generally black, whereas the oolitic rock occurring in the Nittany, though less abundant than that in the Mines, generally has white grains in a dark or black groundmass, and the grains are usually smaller than those of the Mines.

The oolitic rock consists simply of quartz—mostly in the form of chert or chalcedony. That this rock is the direct result of replacement by silica of dolomitic and calcareous oolites there seems to be no doubt, as all gradations from the siliceous to the other types occur, and the siliceous type is found only where calcareous or magnesian types are or have been present. It is commonly believed that calcium (lime) carbonate is and in time past has been extracted from sea water by bacteria and blue-green algae and deposited in the form of oolitic grains. The oolitic chert of the Mines dolomite possibly or even probably originated in this way as an oolitic limestone which was later silicified to chert.

The thickness of the Mines dolomite differs from place to place, but the average is 150 to 200 feet.

Distribution and surface form.—The Mines dolomite occurs as a continuous band extending from a point near the southwest corner of the quadrangle northeastward around the Gatesburg formation in the central portion of the Nittany anticline. Except for a very narrow strip southwest of Mattern Junction, occupied by chert, although this may be Nittany, it is almost completely faulted out from Briarly southwest to the west boundary of the quadrangle. A narrow band also borders the narrow synclinal triangle in the very southwest corner of the quadrangle. The chief surface expression of its distribution is the vast amount of chert and siliceous oolite that occurs on the ground above it.

Fossils and correlation.—The only fossils that have been found in the Mines dolomite of this area are two species of *Cryptozoon* and a species of gastropod. The same fossils occur, the Cryptozoa abundantly, in the Mines dolomite of the type locality in Blair County. In the vicinity of Schoenberger and at Williamsburg, Blair County, gastropods of the genus *Sinuopea* occur in the Mines dolomite, three species of which have been tentatively identified by Ulrich as *S. basiplanata* Ulrich and Bridge, *S. umbilicata* Ulrich and Bridge, and *S. vera* Ulrich and Bridge. On the point of the spur immediately south of Williamsburg and 100 feet above the town is a layer 1 foot thick crowded with these gastropods and taken as the base of the Mines. The species named occur in the Van Buren formation of Missouri, and at least three other distinct species occur in the Copper Ridge dolomite of Alabama. Apparently the same species of *Cryptozoon* also characterize the Copper Ridge dolomite [7] of Alabama and Tennessee.

LARKE DOLOMITE

In the Hollidaysburg and Huntingdon quadrangles, 40 to 50 miles southwest of the Bellefonte quadrangle, the Mines dolomite is succeeded by about 250 feet of dolomite without sandstone or chert, which has been named by Butts [8] the "Larke dolomite." This formation has yielded a few fossils which prove it to be of the age of the Gasconde dolomite of Missouri, the Chepultepec dolomite of Alabama, the Oneota dolomite of Wisconsin, and the chert at the top of the Little Falls dolomite of eastern New York. One of these fossils is *Helicotoma uniangulata*, the main guide fossil of the formation.

The Larke is not generally recognizable or mappable in the Bellefonte quadrangle, but limestone believed to represent the Larke is exposed in an old ore pit 1¾ miles N. 75° W. of Scotia. (See geologic map and pl. 5, *B*.) Here about 200 feet of vertical rock has been exposed. It is mainly dolomite but includes thick layers of fossiliferous limestone near the middle. In this bed of limestone occurs a large gastropod provisionally referred by Ulrich to *Helicotoma winonensis* (Sardeson); a large *Ophileta* shown in cross section and not positively identifiable specifically but comparable to *O. grandis;* and numbers of specimens of a species of *Hemitheca*. The fossils named, including the broad form of *Hemitheca*, are elsewhere known only in the Gasconade dolomite of Missouri or the Oneota dolomite of Wisconsin. As the Larke also belongs to this general zone, the fossiliferous beds at the old ore pit are identified with the Larke.

However, as the Larke is elsewhere unknown in the region and its known area at the old pit is very small, it is mapped with the Stonehenge in what seems to be a small fault block as shown on the geologic map. (See pl. 5, *B*.)

Although the Gatesburg, Mines, and Larke formations carry but few fossils in the Bellefonte quadrangle or elsewhere in Pennsylvania, a large assemblage—brachiopods, 50 species; gastropods, 200 species; trilobites, 150 species; cephalopods, 250 species; total, 650 species—have been obtained and studied by Ulrich from equivalent formations elsewhere. The main significance of the animals which

[7] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 281–680, 1911.

[8] Butts, Charles, Geologic section of Blair and Huntingdon Counties, Pa.: Am. Jour. Sci., 4th ser., vol. 46, pp. 523–537, 1918.

lived at the time these formations were deposited and whose fossils they now contain is that none of the species appears to be exactly the same as any species of the underlying Upper Cambrian formations, and the fauna seems to be equally distinct from that of the succeeding formations of Beekmantown age. These facts are believed to indicate a considerable interval of time between the deposition of the Upper Cambrian formations and that of the Gatesburg and equivalent formations—such an interval as results from the earth movements that produce the breaks between geologic systems. Mr. Butts believes, therefore, that the Gatesburg, Mines, and Larke formations and their equivalents elsewhere constitute in themselves a major stratigraphic and faunal unit of systemic rank, fully coordinate with the other recognized systems. They represent the proposed Ozarkian system of Ulrich in this area.

HIATUS BETWEEN MINES DOLOMITE AND STONEHENGE LIMESTONE

As the Larke dolomite is not generally recognizable and is believed to be generally absent in the Bellefonte quadrangle, there is a hiatus between the Mines and Stonehenge due to its absence.

ORDOVICIAN SYSTEM

The Ordovician system is very highly developed in this quadrangle. The Lower Ordovician is represented by formations of Beekmantown age, which reach a great thickness and include, in ascending order, the Stonehenge limestone, the Nittany dolomite, the Axemann limestone, and the Bellefonte dolomite, and by the Carlim limestone, of Chazy age. The Middle Ordovician is represented by the Lowville, Rodman, and Trenton limestones, and the Upper Ordovician by the Reedsville shale, the Oswego sandstone, and the Juniata formation.

A remarkably fine section of the Ordovician rocks is found in the vicinity of Bellefonte, beginning just south of the town, on Logan Branch of Spring Creek, and extending through the Milesburg gap in Bald Eagle Mountain. Here the whole system from the base of the Stonehenge to the top of the Juniata is mostly exposed. This section of the Ordovician has already been studied and described in some detail by the geologists of the Second Geological Survey of Pennsylvania and more recently by Ulrich [9] and Collie,[10] and the names adopted here for the formations of Beekmantown age are those proposed by Ulrich.

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[9] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 656–660, 1911.

[10] Collie, G. L., Ordovician section near Bellefonte, Pa.: Idem, vol. 14, pp. 407–420, 1903.

BEEKMANTOWN GROUP

The Beekmantown group was named for Beekmantown, Clinton County, N. Y., near which is a good exposure of limestone with abundant specimens of the gastropod genus *Lecanospira*, which characterizes the lower half or so of the Nittany dolomite and may be regarded as the most typical Beekmantown fossil.

STONEHENGE LIMESTONE

Character and thickness.—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.

The section along the road south of Bellefonte on the northwest side of the Nittany anticline was measured. The strike averages N. 70° E. and the dip 40°–50° N. 20° W. The contact with the underlying Mines dolomite, of which several score feet is exposed along the creek, is found near the gate to the old Nittany furnace. Here the shale beds at the base of the Stonehenge are not so marked as in most other sections in the quadrangle or even on the southeast limb of the anticline, and the line between this formation and the Mines is not so distinct as at most other points.

Section of Stonehenge limestone near Nittany furnace, on Logan Branch in the south environs of Bellefonte

	Feet
Nittany dolomite: Hard fine-grained dolomite.	
Stonehenge limestone:	
Highly crystalline layers with reddish iron-stained pebbles and fragments of limestone and fossils. This is the highly fossiliferous bed characteristic of the top of the formation, containing *Eccyliomphalus multiseptarius* (Cleland), *Bellefontia collieana* (Raymond), *Ribeiria parva* (Collie), *Finkelnburgia* cf. *F. wemplei* (Cleland), *Bucania tripla* Whitfield, and other forms	28

Section of Stonehenge limestone near Nittany furnace, on Logan Branch in the south environs of Bellefonte—Continued

	Feet
Stonehenge limestone—Continued.	
Interbedded thin and thick layers of blue limestone with zones of gray crystalline rotten and blotched limestone and dolomite. The upper 50 feet consists of "edgewise conglomerate" and is highly crystalline. A small *Ophileta* and other gastropods occur throughout	476
Dense, rather thick bedded blue limestone with thin beds of crystalline limestone. Greatly crushed zone. Numerous gastropods of new species; *Ophileta* cf. *O. levata* Vanuxem common	100
Edgewise conglomerate and limestone conglomerate with two thin beds of conglomerate containing red silicified clay pebbles and fossiliferous limestone pebbles. Brachiopods plentiful, including *Finkelnburgia* cf. *F. wemplei* (Cleland) and *Ophileta levata* Vanuxem	98
	702

On the south limb of the anticline the following section was obtained. The average dip is 17°.

Section of Stonehenge limestone on Logan Branch west-northwest of Axemann

	Feet
Nittany dolomite: Thin beds of brownish-gray dolomite.	
Stonehenge limestone:	
Crystalline, granular oolitic limestone containing *Eccyliomphalus multiseptarius* (Cleland)	½–3
Dolomitic limestone with fragments of fossils	18
Coarse-grained crystalline oolitic limestone with small reddish pebbles and grains, the lowest beds containing numerous gastropods and the upper bed literally filled with pygidia of the trilobite *Bellefontia collieana* (Raymond). The intervening beds contain numerous fragments of trilobites and gastropods	9
Coarse-grained crystalline oolitic limestone with fragments of trilobites	20
Rather impure thin-bedded limestone	3
Coarsely crystalline pure limestone, with edgewise conglomerate	29
Nearly pure dark-gray to bluish-gray limestone, distinctly bedded	55
Dense bluish impure limestone, very hard and brittle, streaked and blotched with yellowish-brown sandy clay. Some attempts made at quarrying, but quarry abandoned	85
Dense, irregularly fractured blue, brittle, comparatively pure thick- and thin-bedded limestone	136
Very dense, brittle bluish limestone with calcite stringers and spots of calcite as much as three-fourths inch in diameter. Contains *Ophileta* and large gastropods of new species like those seen on north side of anticline	54

Section of Stonehenge limestone on Logan Branch west-northwest of Axemann—Continued

	Feet
Stonehenge limestone—Continued.	
Reddish limestone grading into dense blue crystalline limestone with calcite stringers and numerous blotches and sheets of dark-brown to light-brown and yellowish fine-grained sandy clay, with siderite and dolomite	37
Reddish brittle dolomitic limestone that breaks with a conchoidal fracture. Contains numerous spines of trilobites and one pygidium of a trilobite resembling *Tsinania columbiana* (Weller)	32
Medium thin bedded limestone with little veinlets of calcite and some reddish-spotted granular limestone	23
Alternating thick and thin beds of limestone with thin beds of reddish conglomerate and partings of brown clay	55
Poor exposures of thin-bedded limestone	49
Thin-bedded reddish conglomerate; some of the pebbles are silicified red clay resembling jasper; others are stained by iron oxide; brachiopods numerous	3
Bluish crumbling limestone, grading upward through a dense bluish limestone into a coarse granular limestone	23
Mines dolomite.	
	633

This section is not so thick as the one on the north side of the anticline but in most other respects is very similar. The characteristics of the formation throughout the quadrangle are like those in the Bellefonte section except that the formation becomes much thinner along the strike to the southwest on both limbs of the Nittany Valley anticline. On the north limb of the anticline in that direction the highly fossiliferous upper beds are lacking, and all except the shaly conglomeratic beds near the base are almost or entirely nonfossiliferous. A section made on the road 1¼ miles directly north of State College shows that the formation has thinned to 260 feet, but the characters are similar to those near Bellefonte except for the presence of 25 feet of coarse-grained gray irregularly weathering dolomite just above the middle of the formation and another narrow band a few feet higher.

Distribution and surface form.—The Stonehenge limestone extends in two bands northeastward across the quadrangle along the limbs of the Nittany Valley anticline and swings around the Gatesburg formation on the northeast end of the anticline. On the northwest limb it is faulted out from the vicinity of Briarly southwestward to the west edge of the quadrangle. There are numerous exposures of the formation, and little difficulty is experienced in following the contacts. It forms abrupt cliffs along streams, such as those seen along Spring Creek, and it weathers in places so as to leave isolated flat-topped, mesa-like masses of rock. Sink holes are common near the contact between this formation and the Mines dolomite, the porous character of the dolomite affording a ready circulation of water, which dissolves much limestone near the base of the Stonehenge formation.

There is an area of Stonehenge on the south side of the Pine Hall fault, a narrow strip just northwest of the fault, and a narrow forked area extending 1½ miles into the quadrangle from the southwest corner. In the narrow strip just northwest of the fault mentioned above the Stonehenge is upturned on the south side of a small syncline in which a narrow band of the overlying Nittany dolomite has escaped erosion. (See structure section F–F′, pl. 2.)

Fossils and correlation.—Fossils are abundant in this formation, but unfortunately most of them are new species and therefore not available for correlation. Some well-known species have, however, been found, among them *Finkelnburgia* cf. *F. wemplei* (Cleland), *Bucania tripla* Whitfield, *Ophileta levata* Vanuxem, *Eccyliomphalus multiseptarius* (Cleland), *Bellefontia collieana* (Raymond), *Ribeiria calcifera* Billings, and *R. parva* Collie.

On the basis of the similarity of faunas Ulrich considers this formation equivalent to the Stonehenge limestone of its type locality near Chambersburg, Franklin County, Pa., as described by Stose,[11] and to the Tribes Hill limestone in the Mohawk Valley section in New York. Ruedemann[12] has identified a graptolite from the Stonehenge as *Airograptus furciferus* (*Dictyonema furciferum*) Ruedemann. Rare and obscurely preserved specimens of this form have been collected at an old quarry on Logan Branch near the old Nittany furnace, half a mile southeast of Bellefonte, and at an old quarry in the fault block at the road intersection 1.1 miles due south of Buffalo Run post office. According to Ruedemann[13] this species occurs also in the Deepkill shale near Albany, N. Y., where it is associated with *Didymograptus extensus* Hall and *D. bifidus* Hall, which serve to correlate the Deepkill and therefore the Stonehenge with the Skidavian of England. The Deepkill is correlated with the Beekmantown in general, but this graptolite and another one, *Callograptus salteri* Hall, of the Deepkill, doubtfully identified by Cleland[14] from the Tribes Hill limestone at Tribes Hill, Herkimer County, N. Y., are the only fossils in the Appalachian region common to the Beekmantown and Deepkill.

[11] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (no. 170), pp. 6–7, 1909.
[12] Ruedemann, Rudolph, New York State Mus. Bull. 189, pp. 17–21, 1916.
[13] Ruedemann, Rudolf, New York State Mus. Bull. 285, pp. 90–92, 1930.
[14] Cleland, H. F., Bull. Am. Paleontology, vol. 4, no. 18, p. 7, 1903.

NITTANY DOLOMITE

Character and thickness.—There is no evidence of any physical break between the Stonehenge limestone and the Nittany dolomite, which overlies it. There is, however, a marked lithologic difference in the two formations, as the Stonehenge is almost entirely limestone, whereas the Nittany is composed largely of dolomite, with a great deal of chert distributed through its lower beds in some areas.

The formation was named by Ulrich for the Nittany furnace, near Bellefonte. Many good exposures of the formation are found in the quadrangle, but much the best and most complete section is exposed at Bellefonte, where the following section was measured. Here the strike averages N. 70° E., and the dip ranges between 35° and 50° N. 20° W., with an average of about 47°.

Section of the Nittany dolomite at Bellefonte

	Feet
Axemann limestone: Fossiliferous limestone.	
Nittany dolomite:	
Thick-bedded dark crystalline dolomite, much streaked and blotched, interbedded with light-colored fine-grained sugary dolomite and dense dolomite of cherty texture	665
Dark crystalline thick-bedded dolomite, with lighter beds; a crushed zone and small fault	112
Dark granular coarsely crystalline limestone and dolomite, the latter mottled with gray spots; some light-colored dolomite with a few white sand grains	70
Masses of dark-gray granular oolitic dolomite, emitting when struck an odor like that of hydrogen sulphide; some comminuted cherty dolomite; a little white sand along bedding planes; greatly crushed zone	105
Dense fine-grained white-weathering dolomite with dense gray dolomite that has brownish streaks; highly crushed zone	36
Dark crystalline granular rather decomposed dolomite and interbedded dense dolomitic limestone with yellowish and brownish streaks and bands with iron oxide; a few oolitic limestone layers in upper portion	70
Brecciated fine-grained dolomite and dolomitic limestone with sand grains in the interstices in the breccia. Beds are thin and contain brown and yellowish lamination lines	18
Mixed beds of hard fine-grained light-colored dolomite and darker coarsely crystalline partly decomposed dolomite with masses of chert	88
Hard, dense fine-grained dolomite	45
	1, 209

This section may be regarded as typical of the Nittany, for although it varies somewhat from place to place within the quadrangle the major features remain the same. The thin sandy beds occur throughout the area at much the same horizon, and spherical chert nodules, consisting of silicified heads of *Cryptozoon steeli* Seely, are common and are characteristic of the lower part of the formation. The oolitic beds of the formation are also commonly replaced by silica, as, for example, in a large area extending from Pine Hall and northeast of Bloomsdorf along Penn Valley to Oak Hall, where there are sandy and cherty bands. The dolomite breaks down readily, leaving few exposures and a surface sprinkled with blocks of siliceous oolite and of chert, which is locally abundant. Near the place where Slab Cabin Run crosses the formation there is a band of sandy and calcareous limonite on the surface.

The dolomite weathers in an irregular manner, generally exhibiting a highly pitted surface, which is particularly characteristic of the coarse granular beds.

This formation is quarried a little for road material, lime, and concrete, but much of it is of poor quality.

The thickness of the formation, as obtained from the Bellefonte section above, is 1,209 feet. Possibly this is not the true thickness, as small faults occur which may have changed it a little. The thickness seems to be about the same in other parts of the quadrangle but differs somewhat from place to place.

Distribution and surface forms.—The main area of the Nittany dolomite extends up Penn Valley nearly to Oak Hall, along Nittany Valley to Bellefonte, and thence southwest to Waddle, where it is overridden by the Gatesburg formation along the Birmingham fault. There is a forked outcrop near the west edge of the quadrangle south of Buffalo Run and a very small area in the extreme southwest corner of the quadrangle. State College and the southeastern part of Bellefonte are located mainly on the Nittany. Except near Spring Creek, the surface underlain by the Nittany dolomite is gently rolling, and the land is nearly all arable.

Fossils and correlation.—The few fossils that have been found in the Nittany dolomite include some typical Beekmantown forms, such as several species of *Lecanospira* and *Cryptozoon steeli* Seely. Ulrich also reports *Syntrophina campbelli* (Walcott) and *Hormotoma artemesia* (Billings). The upper part of the Nittany has yielded two new species of *Eccyliopterus* and a new species of *Orospira*.

So far as known *Lecanospira* is confined to the lower part of the Nittany in the Bellefonte region and to the equivalent of the same in the Appalachian Valley generally. The lower part of the Nittany is also about equivalent to the Longview limestone of Alabama and to the part of the typical Beekmantown that crops out near Beekmantown, N. Y., and carries *Lecanospira*, one or more species of which were described and figured by Whitfield [15] as *Ophileta complanata.* The two species of *Eccyliopterus* and the species of *Orospira* occur at Bellefonte above the *Lecanospira* zone; likewise in the Beekmantown from the St. Lawrence Valley to Arkansas they mark a zone higher than the *Lecanospira* zone. In Missouri and Arkansas the zone in which the *Eccyliopterus* and *Orospira* occur lies in the Cotter dolomite, and on this evidence an indefinite zone in the upper half or so of the Nittany is correlated with the Cotter.

AXEMANN LIMESTONE

Character and thickness.—The Nittany dolomite is succeeded by a comparatively pure and moderately fossiliferous limestone, for which Ulrich [16] has proposed the name "Axemann" because it crops out 1 mile south of the village of Axemann, which is 3 miles southeast of Bellefonte. There is a possible objection to this name because the village is situated entirely on the Nittany and Stonehenge formations, but otherwise it is the most suitable name available. The Axemann in general is a body of blue limestone easily separable from the gray dolomite above and below, although in places it is difficult to locate its exact boundaries.

A particularly good exposure of the lower part of the Axemann occurs near the steam laundry in Bellefonte, between the bridge on the main street and the large spring. At this exposure the Axemann consists of layers as much as 2 feet thick of pure coarsely crystalline fossiliferous limestone interbedded with thin-layered impure fine-grained dolomitic limestone. The crystalline beds are partly oolitic and conglomeratic. Most of the pebbles are reddish iron-stained fragments of limestone. Many of the fine-grained layers are spotted with argillaceous material. The coarsely crystalline beds contain many gastropods, fragments of trilobites, and some ostracodes.

The description of this exposure holds very well for the formation throughout the quadrangle except that in some areas it contains a larger proportion of dolomitic layers and a great deal of flint and chert. Dolomite becomes more abundant to the west, on the north limb of the Nittany anticline. As a rule the flint concretions are more characteristic of the purer limestone beds of the formation in this quadrangle, and the chert of the dolomitic strata. In one locality, almost a mile south of State College, limonite has replaced the beds, forming an ore deposit that has been mined.

[15] Whitfield, R. P., Am. Mus. Nat. History Bull., vol. 2, pl. 7, figs. 18–25, 1889.
[16] Ulrich, E. O., op. cit., p. 657.

On the hill between the west fork of Buffalo Run and Mattern Junction, in the southwestern part of the quadrangle, there is a large mass of calcite in the limestone, which is evidently a deposit along a fracture, as it may be traced westward to the next north-south road, where a sharp fold occurs in the formation. At the locality first mentioned there is a mass at least 25 feet long, 20 feet wide, and 7 feet high. Some attempts have been made to quarry the stone for marble. It shows a roughly bedded structure and is so highly fractured that large blocks suitable for architectural purposes cannot be obtained. Blocks as much as 4 by 2 by 2 feet have been removed from the mass, but owing to the highly crystalline, coarse-grained, checked, and fractured character of the material it could not be used. No rock could be found in contact with the calcite, but it is surrounded by Axemann limestone, and this large mass may have occupied a cavity in that rock. Its westward extension is traced by fragments on the surface.

The thickness of the Axemann differs from place to place. At Bellefonte it is 158 to 200 feet, and in the narrow strips southwest of Mattern Junction it seems to range from 50 to 200 feet. The Axemann reaches its maximum thickness of about 500 feet at State Colledge and near Oak Hall. The difficulty of locating the boundaries everywhere consistently may account in part for the differences in thickness given above.

Distribution and surface form.—The Axemann limestone crops out in a band along the northwest limb of the Gatesburg anticline and is well exposed and traceable from Bellefonte southwest to Knox School. Limestone, with fossils believed to be from the Axemann, was found half a mile west of Hunter Park. From that locality southwest to a point 1 mile south of Buffalo Run post office it could not be found, but at that point it is exposed on opposite sides of a narrow anticline. From thence southwest to Warriorsmark, a distance of about 10 miles, no exposures could be found and the exact location of its outcrop is unknown, but there is reason to believe that it crops out as mapped. Along the southeast limb of the Gatesburg anticline it crops out as far as Struble, thence swings around the southwest end of the Nittany Mountain syncline to a point east of Oak Hall, where it turns southwestward after crossing the axis of the Penn Valley anticline. Thence it is traced southwestward to a point near the middle of the south boundary of the quadrangle and continues to the southwest beyond the quadrangle. Northeast of Bellefonte the outcrop has been offset eastward by the Bellefonte fault beyond the boundary of the quadrangle.

The Axemann produces no distinctive topographic features, the surface underlain by it being entirely harmonious with those of the dolomite formations bounding it on both sides. In some places considerable chert and flint are found on the surface.

Fossils and correlation.—The formation is fossiliferous throughout the quadrangle, and in some places the chert contains numerous specimens. A fragment of chert filled with gastropods, obtained from the hollow on the south side of State College, was examined by Ulrich, who reports that one gastropod may be *Trochonema tricarinatum* Billings and that another is related to *Ophileta strigata* (Collie). Specimens from an outcrop on the hill just north of Shingletown, in the southeastern part of the quadrangle, were identified by Ulrich as *Ophileta strigata* (Collie), *Liospira* sp., *Hormotoma artemesia* (Billings), *Coelocaulus?* cf. *C. linearis* (Billings), and *Ribeiria* n. sp. In a collection from the Axemann just southeast of Bloomsdorf *Maclurea? affinis* (Billings) was recognized, and from the outcrop along the creek northwest of Waddle *Maclurea? affinis* (Billings), *Ophileta strigata* (Collie), and *Hormotoma artemesia* (Billings) were obtained. In all these outcrops *Ophileta strigata* is very abundant. In addition to these species *Hormotoma gracilens* (Whitfield), *Maclurea affinis* (Billings), *Sinuites rossi* (Collie), and *Jeffersonia amplimarginata?* (Billings) have been found at Bellefonte. A species of *Deltatreta* is very common in the Axemann throughout the Nittany Valley. As the upper part of the Nittany has been correlated with the Cotter dolomite, the Axemann is considered late Cotter or post-Cotter.

As shown by Ulrich and Collie, the Axemann falls also within the limits of the Beekmantown of Champlain Valley and adjacent areas in Canada, and the fauna has been considered to be more or less closely related to that of the limestone at Fort Cassin, at the top of the Beekmantown of Vermont.

BELLEFONTE DOLOMITE

Character and thickness.—"Bellefonte dolomite" is the name applied by Ulrich to a thick formation consisting almost entirely of dolomite that lies between the Axemann limestone below and the Carlim limestone above. At most places in the quadrangle it is separated from the Carlim limestone by a fairly sharp line of demarcation, and in some places it is distinctly marked off from the Axemann. Elsewhere, however, it grades into these formations by intercalation of the dolomite beds with the limestone. A limestone layer about 25 feet thick is found in the southern part of the quadrangle 75 feet above the base of the formation.

A type locality of the formation is Bellefonte, where a good section of the formation is exposed on the main street northwest of the bridge that crosses Spring Creek near the railroad station. The average dip of the strata in this section is 55° NW. A section is given below.

Section of Bellefonte dolomite in Bellefonte

	Feet
Carlim limestone.	
Bellefonte dolomite:	
Dense, fine-grained, compact dolomite, weathering whitish and characterized in lower beds by a distinct conchoidal fracture and siliceous appearance; grading upward into an impure shaly dark-gray dolomitic limestone. Upper 100 feet not exposed	510
Gray dolomite, weathering white and mixed with thin wavy and locally shaly layers. Chert concretions are common. The upper limit marks the horizon of the sandstone bed found in the formation along the strike half a mile to the southwest but indistinct in this section	196
Coarsely crystalline magnesian limestone or dolomite beds with fine-grained gray and brownish impure dolomite, showing wavy yellowish and brownish laminations	197
Covered by streets	212
Gray magnesian limestone or dolomite with a few *Hormotoma*-like gastropods inseparably embedded in the matrix of the rock. Quartz grains fairly common. Near station of old Central of Pennsylvania Railroad	101
Interbedded thick brownish crystalline dolomite and fine-grained bluish-gray thin-bedded dolomite and magnesian limestone, with wavy laminations colored red and yellow by iron. These beds grade into denser grayish to brownish-blue beds that weather very white on the surface. Concretions and irregular layers of chert are common along the irregular and hummocky bedding planes of the magnesian limestone, being more abundant in the upper layers	425
Covered by streets	590
Axemann limestone.	
	2, 231

This section is fairly illustrative of the general character of the formation in this region, although the texture of the beds differs from place to place. No fossils were found elsewhere in the formation. The tendency for certain of the beds of dolomite to weather with a very white surface is characteristic. Also throughout the quadrangle a thick bed of very dense dolomite, of siliceous appearance and breaking with a striking conchoidal fracture, is almost everywhere immediately above the sandstone mentioned in the preceding section and described in the next paragraph.

Sandstone member.—An interesting feature of the Bellefonte dolomite is a sandstone member of wide extent. Though scarcely any trace of it can be found in the section at Bellefonte, it is known to be present just northeast of the station of the old Central Railroad of Pennsylvania, where it has been seen by Ulrich. Here it is about 1,200 feet below the top of the Bellefonte. At this point it contains fragments of gastropods or trilobites. It becomes better developed gradually along the strike to the southwest, reaching a thickness of 7 feet near Coleville. Beyond this point it continues as a distinct bed to the southwest of Stevens, where it gradually thins out. Near Pleasant Gap, 4 miles southeast of Bellefonte, across the strike of the formations, this sandstone is scarcely perceptible, but at the schoolhouse near Dale Summit, 4 miles southwest of Pleasant Gap, it has a thickness of 15 feet and forms a distinct ridge. Southwestward along the strike of the Dale Summit exposure the bed becomes thinner, but it can be traced around the southwest end of the Nittany Mountain syncline, although in many places it is recognized only as a thin yellowish sandy oxidized limestone. In places, however, it forms a distinct sandstone bed and can be easily followed. Although this sandstone is generally not exposed along the southeast flank of Nittany Mountain, fragments indicate its presence. It forms a distinct ridge southwest of Linden Hall, in the southeast corner of the quadrangle, where it is about 12 feet thick and consists of thick beds, which on weathering leave large blocks on the surface. The sandstone thins northeast of Linden Hall but can be easily traced to the edge of the quadrangle. It thins also southwest of Linden Hall and is lost near Boalsburg but reappears as a distinct band at the border of the quadrangle, 1½ miles southwest of Shingletown.

This sandstone member of the Bellefonte dolomite consists of white sand grains that are as a rule perfectly rounded. In some places it is a conglomerate, with pebbles of limestone and in fewer places small pebbles of chert or quartz. Small unidentifiable fragments of trilobites and gastropods are common. Some parts of the rock contain oxidized iron-bearing clay.

The thickness of the Bellefonte dolomite at Bellefonte, as given in the section on page 30, is 2,231 feet. So far as known it preserves a comparable thickness southeast of the Nittany anticline, but its thickness must decrease considerably southwestward along its outcrop northeast of the anticlinal axis, for in the latitude of Waddle the width of its outcrop is only 1,500 feet and, as the beds are vertical, its thickness may equal but cannot exceed that amount.

Distribution and surface form.—The outcrop of Bellefonte dolomite extends as a continuous band along the northwest limb of the Nittany Valley anticline to the fault east of Bellefonte, north of which it is offset several hundred feet to the east. It runs along the southeast limb of the same anticline, swinging around the southwest end of Nittany Mountain and continuing northeastward along the southeast flank of this mountain beyond the eastern border of the quadrangle. Some distance east of the quadrangle it swings back and follows the southeast side of the Penn Valley anticline and the north limb of the Tussey Mountain syncline to the south border of the quadrangle.

The Bellefonte does not form any striking type of topography. Low hills and valleys are developed on its outcrop, but where the sandstone member is thick it generally forms a low ridge with large blocks of the sandstone on the surface. Exposures of the formation are numerous, and good sections may be seen near Oak Hall, between Axemann and Pleasant Gap, and elsewhere. It weathers to a good soil and does not leave so much chert and flint on the surface as the Nittany dolomite, although fragments of dolomite commonly remain. The nonsiliceous portions of the formation may be burned for lime, and some beds produce fairly good building stone.

Fossils and correlation.—Fossils are comparatively rare in the Bellefonte dolomite. Some have been found at Bellefonte, but all of them are too firmly embedded in the matrix to permit their extraction and identification. Ulrich mentions one gastropod like *Hormotoma artemesia* (Billings). The character of the few fossils found and the fact that the Bellefonte is closely related to the Axemann limestone below justify its assignment to the Beekmantown group. Its exact equivalent in the typical Beekmantown has not been definitely determined, however, although there are considerations suggesting that it may extend as low as the beds in Vermont that carry the Fort Cassin fauna or perhaps to some still lower horizon. The occurrence near Carlim, 2½ miles northeast of Williamsburg, Blair County, of a new and undescribed species of *Ceratopea* in the Bellefonte shows that the formation includes beds of the same age as the Smithville formation of northern Arkansas, in which this same species of *Ceratopea* is extraordinarily abundant. It has also been collected in the Warm Springs Valley, Bath County, Va. The Smithville formation carries the Fort Cassin fauna, of upper Beekmantown age, and from this it would appear that the lower portion of the Bellefonte in Blair County, as well possibly as the Axemann limestone, is to be correlated with this division.

CARLIM LIMESTONE

Character and thickness.—The Bellefonte dolomite, the topmost formation of the Beekmantown group, is succeeded by limestone of Chazy age that has been named the "Carlim limestone" by Butts,[17]

[17] Butts, Charles, Geologic section of Blair and Huntingdon Counties, central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 46, p. 526, 1918.

from the old town and quarry of Carlim, 2 to 3 miles northeast of Williamsburg, Blair County, Pa.

In Blair and Huntingdon Counties, where exposures at a few places permit examination, there is no sharp lithologic boundary between the Bellefonte dolomite and the Carlim limestone, but the one passes into the other through a varying thickness of dolomite, including layers of pure-blue fossiliferous limestone of Carlim type from a few inches to 5 feet thick. These transition beds as a whole range in thickness from a few feet to 50 feet; the maximum thickness is exposed at the southeast side of the quarries at Union Furnace, in Huntingdon County. Aside from these transition beds, which are probably present in Centre County, the Bellefonte and Carlim are lithologically distinct.

The lower part of the Carlim is rather pure limestone in layers a few inches to 2 feet thick. This limestone is prevailingly compact and bluish or dove-colored. Near the bottom there is commonly a few feet of dark compact limestone, tending to have a conchoidal fracture, and this rock is almost invariably fossiliferous with small ostracodes and leptaenoid or strophomenoid brachiopods. The entire lower 250 feet or so of the Carlim is rather pure carbonate of lime and has been largely quarried in Blair and Huntingdon Counties for flux for use in the blast furnaces in Pittsburgh.

The upper 10 to 50 feet of the Carlim is an argillaceous and siliceous dark, highly fossiliferous limestone, commonly showing streaks and blotches of yellowish-gray clayey material on weathered surfaces. As much as 25 percent of insoluble material is reported in this bed in the quarry at Franklin Forge or Ganister, Blair County. Owing to its impurity, this bed is not quarried for chemical uses but is commonly left as a rib in the quarries as the pure beds of Carlim limestone below and of the Lowville limestone above are quarried out (pl. 6, *B*). This impure bed has been set off as a member of the Carlim and named the "Lemont argillaceous limestone member", from the town of Lemont, in this quadrangle, as it is well exposed in a railroad cut a short distance south of the town.

An interesting feature associated with the Lemont member is the presence of thin layers of bentonite both above and below it at Bellefonte and of at least one layer below it at the quarry near Oak Hall (pl. 6, *A*). This bentonite is derived from volcanic ash and shows that in Carlim time there were active volcanoes in some unknown region so near to this locality that at the time of eruption dust was blown over the area, settled upon the water, and finally accumulated on the bottom as layers, which in the vicinity of Bellefonte do not exceed a foot in thickness.

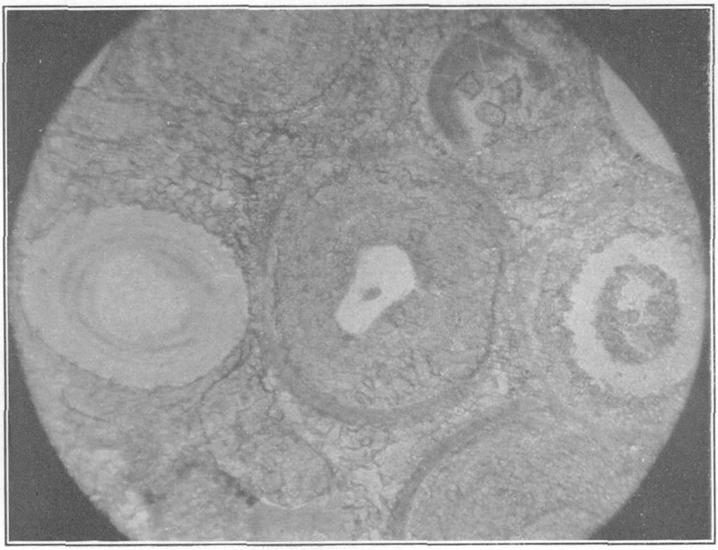
At the quarry near Oak Hall about 175 feet of Carlim below the Lemont member is exposed, but the exposure does not extend to the bottom. The top of the Lemont member here has not been precisely identified, but at least 40 to 50 feet is known to be Lemont, making the full thickness of the Carlim exposed in the quarry 215 feet. According to Ulrich [18] the thickness of the Carlim at Pleasant Gap quarry is 375 to 450 feet, and according to both Ulrich and Butts, the thickness at Bellefonte is somewhat more than 400 feet. The thickness of the Lemont argillaceous member at Bellefonte is about 10 feet, as shown in plate 6, *A*.

Distribution and surface form.—The Carlim limestone crops out in three narrow bands—one northwest of and parallel to Tussey Mountain, passing about 1,000 feet southeast of Boalsburg; a belt paralleling Nittany Mountain on both sides, passing through the quarry near Oak Hall and the quarry at Pleasant Gap, just east of the quadrangle, and appearing in a narrow triangular area in a syncline northest of Penn; and a belt about three-quarters of a mile southeast of and parallel to Bald Eagle Mountain. It is best exposed at the Oak Hall quarry and along the road to Milesburg, in the northwest environs of Bellefonte. The Carlim does not give rise to any distinctive topographic features.

Fossils and correlation.—The most significant fossil for correlation is *Maclurea magna* (Lesueur) of the Lemont member, found at Lemont and near Oak Hall and elsewhere in central Pennsylvania. This species shows here about all the variations exhibited by a large suite of specimens from the middle Chazy Crown Point limestone on Valcour Island, Lake Champlain. Other fossils of the Lemont also associated with the *Maclurea* on Valcour Island are *Rafinesquina champlainensis* Raymond, found at Pleasant Gap, and *Hebertella vulgaris* Raymond, together with *Glyptorthis* of the *bellarugosa* type, less plentiful than *Hebertella vulgaris*, both of which occur generally in the Lemont of Centre, Blair, and Huntingdon Counties. The Lemont carries a good many fossils, mainly Bryozoa and Brachiopoda, of less significance for correlation. *Maclurea magna* and its varieties, as well as some or all of the other fossils specifically named above, occur also in the Lenoir limestone of Virginia, Tennessee, and Alabama, the *Maclurea* being especially characteristic of the Lenoir throughout. *M. magna* is also reported from the Ridley limestone of the Stones River group of the Nashville region, central Tennessee. The Lemont limestone member of the Carlim is confidently correlated with the Crown Point limestone of northeastern New York, the Lenoir limestone of the Appalachian Valley, and the Ridley limestone of the Central Basin of Tennessee.

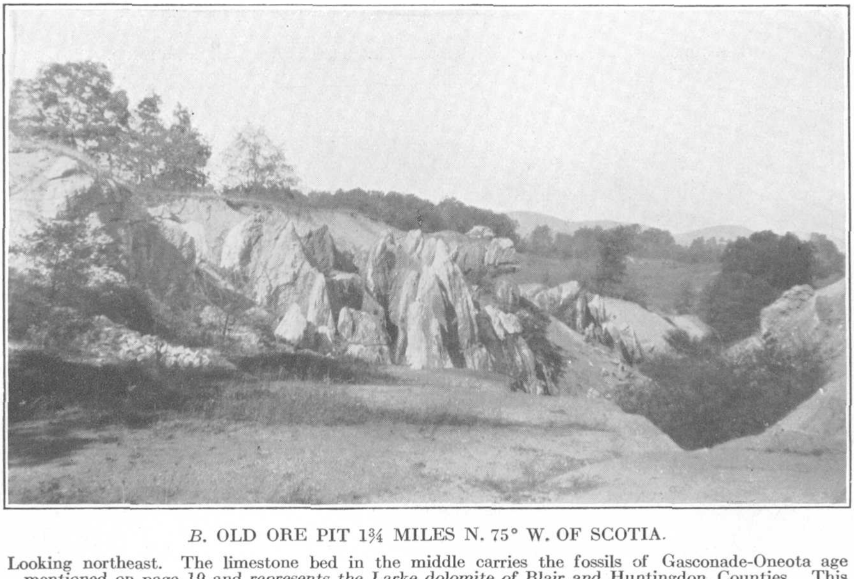
The part of the Carlim below the Lemont member is not so fossiliferous as the Lemont but has some fossils, mainly corals (*Tetra-*

[18] Ulrich, E. O., personal communication.



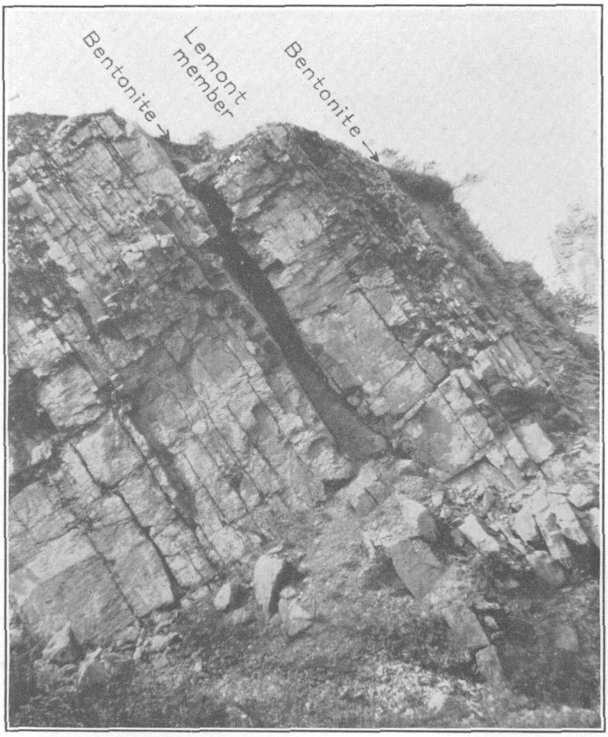
A. PHOTOMICROGRAPH OF A THIN SECTION OF OOLITIC CHERT FROM THE MINES DOLOMITE, SHOWING OOLITIC GRAINS.

Photograph by E. S. Moore. Enlarged 45 diameters.



B. OLD ORE PIT 1¾ MILES N. 75° W. OF SCOTIA.

Looking northeast. The limestone bed in the middle carries the fossils of Gasconade-Oneota age mentioned on page 19 and represents the Larke dolomite of Blair and Huntingdon Counties. This photograph shows the general conditions of outcrop of the limestone and dolomite formations of the region and the slight chance of detecting a thin formation like the Larke.

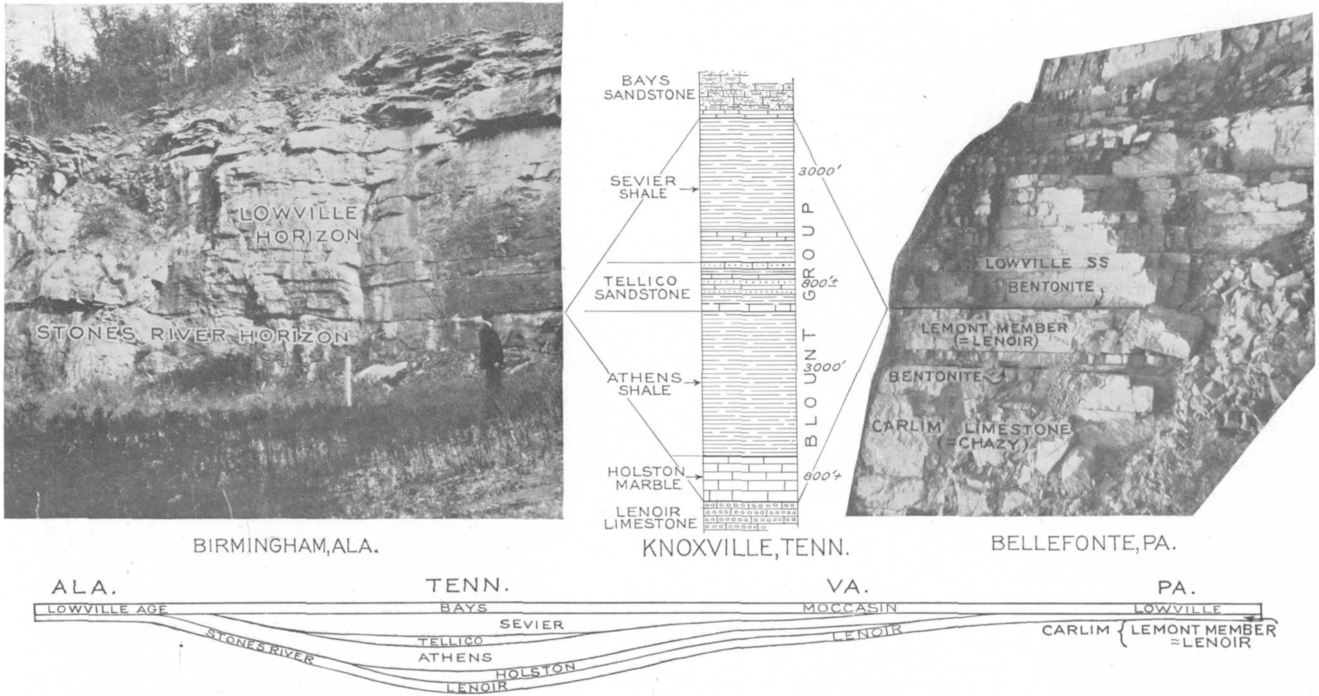


A. LEMONT ARGILLACEOUS MEMBER OF CARLIM LIMESTONE.

Beds of bentonite (volcanic ash) about 1 foot thick above and below. Quarry in northwest edge of Bellefonte (shown in pl. 9, *A*), looking southwest. Photograph by Charles Butts.

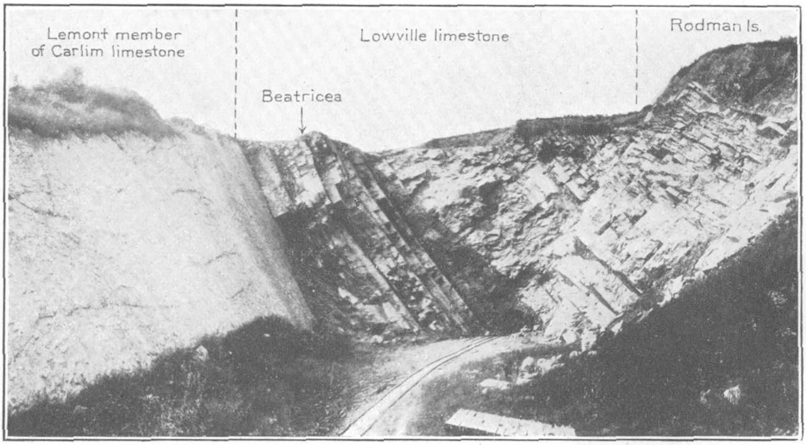
B. RIB OF LEMONT ARGILLACEOUS LIMESTONE MEMBER OF CARLIM LIMESTONE.

Lowville limestone on left and Carlim on right. Old quarry on Elk Run 2 miles south of Tyrone. Photograph by Charles Butts.



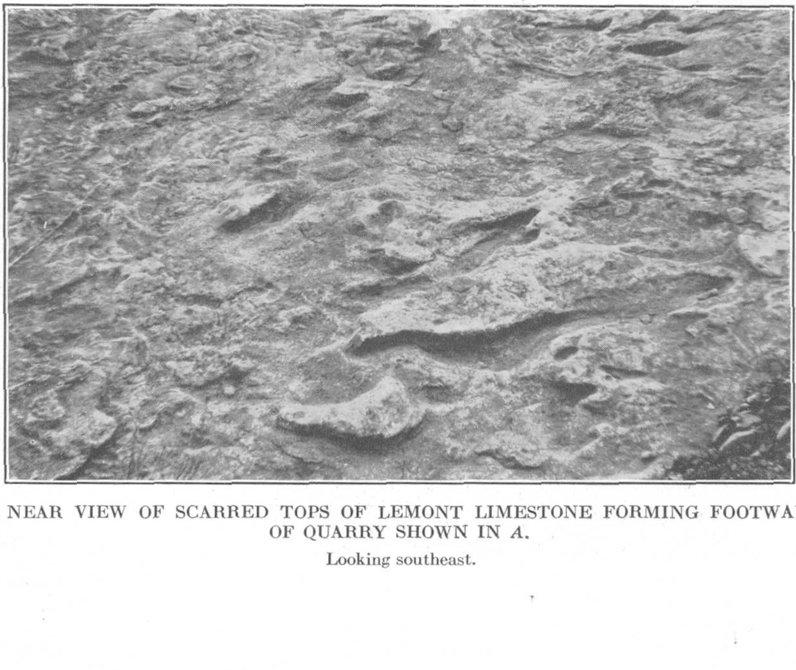
VIEWS AND SECTIONS SHOWING DISTRIBUTION AND STRATIGRAPHIC RELATIONS OF THE BLOUNT GROUP.

Note the parallelism of the bedding shown in the photographs. Vertical uplift without deformation between the deposition of the Lenoir-Carlim and that of the Lowville is indicated. The photograph on the left was taken in an old quarry at Clifton Terrace, Birmingham, Ala., looking southeast, and the one on the right was taken at the active limestone mine on Buffalo Run in the west environs of Bellefonte about half a mile southwest of the old quarry shown in plate 8, *A*, looking southwest. The dip here is about 60° NW., but the photograph has been rotated to a horizontal position.



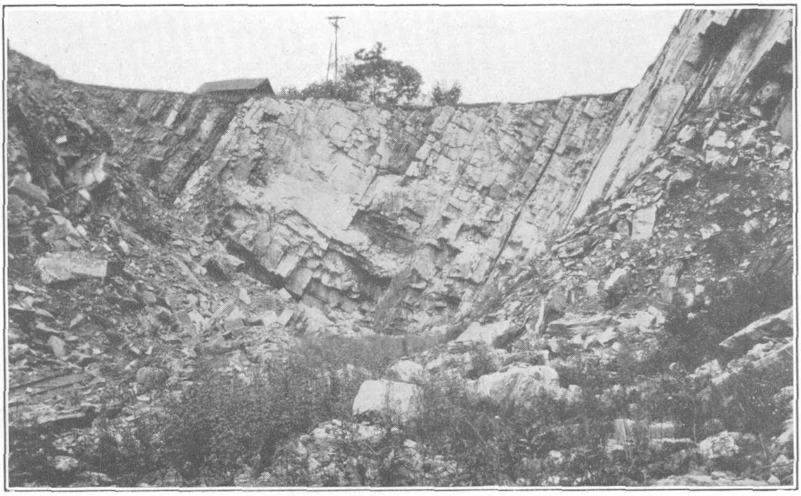
A. OLD QUARRY JUST SOUTHWEST OF ACTIVE LIMESTONE MINE IN WESTERN ENVIRONS OF BELLEFONTE.

The footwall is Lemont limestone carrying here *Protorhyncha ridleyana* and *Glyptorthis bellarugosa*, Chazyan fossils. It is deeply scarred and furrowed, as shown in *B*. A layer of bentonite lies between the footwall and the overlying Lowville. It is the top bed shown in plate 6, *A*. It has weathered out, leaving a thin but visible vacant space. At 26 feet higher and about half an inch above the bottom, as shown in the photograph, is a thin band of black shaly limestone carrying *Beatricea gracilis*. It is the same black band shown in plate 9, *A*. The beds through 10 feet below the black shaly layer carry *Tetradium cellulosum* and *T. columnare*(?). The lower 16 feet appeared unfossiliferous except in the bottom (8 inches to 2 feet), where ostracodes and *Zygospira recurvirostris* occur. Looking southwest.



B. NEAR VIEW OF SCARRED TOPS OF LEMONT LIMESTONE FORMING FOOTWALL OF QUARRY SHOWN IN *A*.

Looking southeast.



A. OLD QUARRY IN LOWVILLE LIMESTONE IN NORTHWEST EDGE OF BELLEFONTE, ON NORTHEAST SIDE OF MAIN ROAD TO MILESBURG.

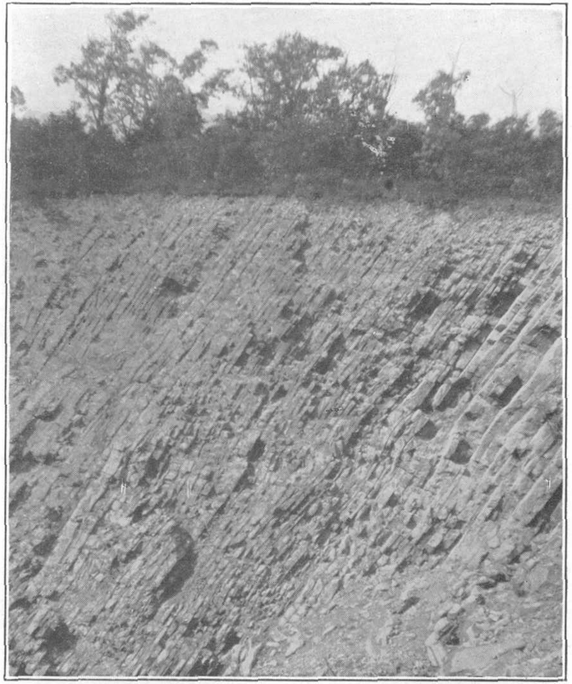
The black line on the right at the far end is made by a black carbonaceous shelly rock that in places at least is crowded with *Beatricea gracilis* Ulrich ms. and *Tetradium cellulosum* (Hall). The bottom of the quarry is about 10 feet below this bed, and the bottom of the Lowville is about 10 feet lower. The contact of the white limestone of the Lowville and the dark limestone of the Rodman intersecting the upper margin of the quarry in line with the left end of the roof of the barn is very distinctly shown. The upper bentonite bed of plate 6, *A*, is probably the dark band about a quarter of an inch to the left of the upper right corner. Looking northeast.

B. SUN CRACKS IN LOWVILLE LIMESTONE.

In quarry shown in *A*. Photograph by E. S. Moore.

A. RODMAN LIMESTONE BETWEEN THE THICK-BEDDED WHITE LOWVILLE LIMESTONE BELOW AND THE THIN-BEDDED TRENTON LIMESTONE ABOVE.

Besides the darker color of the Rodman its granular and irregular laminated texture is visible just above the contact with the Lowville. Same quarry as shown in plate 9, *A*. Looking northwest.



B. THIN-BEDDED TRENTON LIMESTONE IN QUARRY AT UNION FURNACE, HUNTINGDON COUNTY.

Looking northeast. Photograph by Charles Butts.

dium), bryozoans, ostracodes, trilobites, and brachiopods, well distributed throughout its thickness. Among the most significant fossils are *Tetradium syringoporoides* Ulrich, *Protorhyncha* cf. *P. ridleyana* (Safford), another species of *Protorhyncha*, and *Helicotoma tennesseensis* Ulrich and Schofield, found at Sparr, Blair County; *Bathyurus acutus* Raymond? and *B. superbus* Raymond?, found at Roaring Spring, Blair County; *Coelochilina* cf. *C. aequalis* (Ulrich), found at Sparr; and *Leperditia pinguis* Butts. Most of these fossils occur in the middle or lower part of the Stones River group of central Tennessee, and the trilobites named occur in the Pamelia limestone of northern New York and Canada, although the Carlim species may not be exactly the same. *Coelochilina aequalis* (Ulrich) is elsewhere known from the limestone in the bottom of the gorge of the Kentucky River at Highbridge, which is identified by Ulrich as Ridley. An interesting occurrence is a species of *Syringopora* found at Royer, in Blair County. Apparently this is the earliest known occurrence of the genus. What appears to be the same species occurs in the Lenoir limestone of eastern Tennessee and in the limestone at Highbridge. The evidence seems adequate to establish the middle Chazy and middle and possibly early Stones River age of the Carlim limestone as a whole.

HIATUS BETWEEN CARLIM LIMESTONE AND LOWVILLE LIMESTONE

The Blount group of the southern Appalachians, 6,000 to 8,000 feet thick in the Knoxville region, Tennessee, is absent in this region (pl. 7).

In a recent article[19] Mr. R. R. Rosencrans has made the following statement: "Data have been presented which point to the conclusion that the Lemont member of the Carlim of the type section is in part equivalent to beds which Butts (who proposed this term) has mapped as being much younger in age. This interpretation of the data [the interpretation of Rosencrans] indicates that the supposed hiatus, equivalent to several thousand feet of sediments, which has been said [by Butts] to exist at the base of the quarry rock of the Bellefonte section is not present." In answer to this opinion it is here affirmed that the bed between the two bentonite layers shown in plate 5 is the Lemont member of the Carlim limestone. It is probably the limestone between bentonite beds C and D of section 3, plate 3, of the paper by Rosencrans. This limestone is continuous from Elk Run (see pl. 6, *B*), 1 mile south of Tyrone, where *Hebertella vulgaris*, a Chazyan brachiopod, occurs, through the Stover quarry, 2 miles or so northeast of Tyrone, to Bellefonte. In an old quarry 1 mile west of Bellefonte (pl. 8, *A*) the Lemont carries *Protorhyncha ridleyana*, a brachiopod common in a limestone in the gorge of the Kentucky River at Highbridge, Ky., that is correlated with the Ridley limestone of the Stones River group. At Lemont, Oak Hall, and Naginey, north of Lewistown,

[19] Am. Jour. Sci., 5th ser., vol. 27, pp. 131–132, February 1934.

Mifflin County, Pa., the Lemont carries *Maclurea magna*, the main guide fossil of the middle Chazy Crown Point limestone of Lake Champlain and of the Lenoir limestone of Virginia and Tennessee. *Maclurea magna* also occurs in the limestone of the gorge at Highbridge.

The formation immediately overlying the Lemont member of the Carlim in the Bellefonte quarries is the Lowville limestone, characterized by *Beatricea gracilis* and *Tetradium cellulosum*, which are the guide fossils of the Lowville from Canada to Alabama. Both fossils occur together in the black shaly calcareous band near the bottom of the quarry shown in plate 9, *A*. The black band is about 26 feet above the upper bentonite bed of plate 6, *A*. It is plainly shown above the Lemont near the bottom of the quarry of plate 8, *A*.

Owing to its impurities and unsuitability for use as fluxing rock or for lime, the Lemont is generally left as the footwall of all the quarries for chemical rock in the Lowville in central Pennsylvania. Quarrying practice is a certain guide to the recognition of the Lemont.

It may be unqualifiedly affirmed and confidently accepted that the Lowville rests upon the middle Chazy in this region. In the Appalachian Valley through Virginia and Tennessee the middle Chazy is represented by the Lenoir limestone. In the extreme northwestern belts of the valley the same rule prevails as in central Pennsylvania: the Lowville, with its characteristic fossils, occurs next above the Lenoir (=Ridley), as in Hightown Valley, northwest of Monterey, Va., and at Cumberland Gap, Va.–Tenn. In the middle and southeastern belts of the valley, however, the Blount group intervenes between the Lenoir and Lowville. The Blount group was first recognized by Ulrich and is composed in ascending order of Holston marble, Whitesburg limestone, Athens shale or limestone, Tellico sandstone, and Ottosee limestone, aggregating as a maximum 6,000 to 8,000 feet. None of these formations occur in Pennsylvania. Now it happens that, as in Rye Cove, Scott County, Va., the Lowville with *Beatricea gracilis* directly overlies the Ottosee and is therefore younger than the Blount group. Many other places could be cited where this relation exists and can be seen. It likewise happens that, as at Knoxville, Tenn., and Lexington, Va., the Holston marble immediately overlies the Lenoir limestone, which carries *Maclurea magna* and is the southern equivalent of the Lemont limestone. The postulated hiatus therefore does exist. The corroded upper surface of the Lemont limestone (see pl. 8, *B*) affords additional evidence of exposure to air or water within or during a long period of nondeposition, probably accompanied by corrosion and subaqueous denudation. Furthermore, the intercalation of the Blount group between the Lenoir and Lowville has been traced by Ulrich and Butts, mile by mile, from northern Virginia to Alabama. The relations can be easily recognized by any stratigrapher who will traverse the valley from north to south. The statement that a hiatus exists is thus based on the conclusions of competent stratigraphers who have spent much time through many years in acquiring first-hand knowledge of the facts.

LOWVILLE LIMESTONE

Character and thickness.—The Lemont member of the Carlim limestone is overlain by the Lowville limestone, named from the town of Lowville, Lewis County, N. Y. This formation was originally named † "Birdseye limestone"[20] by Amos Eaton, one of the early geologists of New York, the designation being suggested by the "eyes" or light-colored specks, due in part to a characteristic fossil supposed to be a form of coral and now known as *Tetradium cellulosum* (Hall).

In the Bellefonte region the upper part of the Lowville is the well-known quarry rock. The following section indicates the general character of the formation:

Section of Lowville limestone in Bellefonte region

[By E. S. Moore. See pl. 9, *A*]

	Feet
Bluish-gray, pure, dense limestone with conchoidal and irregular fracture, dotted with specks of clear spar or white calcite and streaked with veins of calcite. Fossils rare. Quarry rock	60
Dark crystalline limestone with shaly partings, containing *Beatricea*. Unusual examples of sun cracks in limestone	23
Light bluish-gray, very dense, hard limestone, with splintery fracture; highly fossiliferous; ostracodes and crinoid stems abundant, but fossils usually show only on weathered surface. *Tetradium cellulosum* (Hall) common	67
	150

The sun cracks occurring in the limestone below the quarry bed are a striking feature. They are well exposed in the quarry beside the road between Bellefonte and Milesburg, and at this point many of the cracks are filled with pyrite. The presence of these cracks points to the shallow-water and clastic origin of at least a part of the Lowville limestone. (See pl. 9, *B*.)

At the Pleasant Gap quarries, 1¼ miles east of Pleasant Gap station, the good quarry rock consists of a dense bluish-gray brittle limestone, which breaks with a distinct conchoidal and irregular fracture and is spotted or streaked with specks and veinlets of calcite. The high-grade rock, which may be used for chemical and other pure limes, has a thickness of 30 feet. At the base of this high-grade rock is a shale bed underlain by 20 feet of dark crystalline limestone with 4 to 6 inches of soft black shale in the middle. This limestone is used for flux in blast furnaces. Above the best quarry rock lies 80 feet of very dark gray (in some places almost glossy black on surface) massive crystalline limestone containing a few brachiopods that cannot be separated from the rock. This rock also is used for flux.

[20] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U. S. Geological Survey. Quotation marks, formerly used to indicate abandoned or rejected names, are now used only in the ordinary sense.

The description here given would be characteristic of the quarry rock for most of the quadrangle, but more details will be found in the section on economic geology (p. 99). The thickness of the high-grade rock ranges from 30 to 90 feet and that of the dark crystalline limestone quarried above and below the pure beds has a much greater range.

Distribution and surface form.—The quarry beds of the Lowville generally form outcrops that project from low ridges, rising above the general level, and it is an easy matter to trace this formation. Fragments of pure limestone are also left on the surface in many places. Otherwise there is nothing striking about the surface features of the Lowville limestone unless it is a tendency in some places to form sink holes. It usually yields on weathering a very productive soil.

The Lowville limestone can be traced along the southeast side of Bald Eagle Mountain, as the quarry beds supply good exposures, and most of the Lowville has been exposed in large quarries northeast of the central part of the quadrangle. The formations are offset about a quarter of a mile by the large fault a mile northeast of Bellefonte, and this offset led to the discovery of the fault. The quarry rock on the north side of the fault trace has been brought opposite the Bellefonte dolomite on the south side, whereas the quarry rock on the south side is opposite the Trenton limestone or Reedsville shale.

Southwestward from the White Rock quarries, east of Pleasant Gap station, the pure quarry bed or "chemical lime" decreases in thickness, and the Lowville, carrying *Tetradium cellulosum* (Hall), thins out completely just east of the Lemont railroad station. In the railroad cut just south of Lemont the Rodman limestone, or even the Trenton, seems to lie immediately above the Lemont argillaceous limestone member of the Carlim, carrying *Maclurea magna* (Lesueur). The Lowville is not known along the southeast slope of Nittany Mountain but presumably is present, although not exposed there, being only locally absent at Lemont and northeastward beyond the quarry at Oak Hall.

The Lowville is present along the north side of Tussey Mountain, but so far the pure quarry rock has not been found.

The thickness of the Lowville is generally about 150 feet in the Bellefonte region.

Fossils and correlation.—From specimens submitted Ulrich has identified the following fossils: From rock obtained 70 feet below the good quarry bed northwest of Briarly, *Tetradium* resembling *T. halysitoides* Raymond, *Tetradium cellulosum* (Hall), and *Leperditia* cf. *L. fabulites* (Conrad); from the quarry bed at the White

Rock quarries, *Leperditia* cf. *L. fabulites* (Conrad) and *Leperditia* n. sp.; just beneath the quarry bed northwest of McBride Gap, *Tetradium* n. sp., common in the Lowville; just above the Lemont limestone in the railway cut at Lemont, *Tetradium cellulosum* (Hall) and *Leperditia* n. sp. *Beatricea gracilis* Foerste and *Tetradium cellulosum* (Hall) have been found at the base of the quarry bed at Bellefonte and in the Lowville south-southeast of Linden Hall. Near Buffalo Run post office about 10 feet of limestone near the bottom of the Lowville is almost entirely made up of *Tetradium columnare* (Hall). In Blair County *Streptelasma profundum* (Conrad) occurs. The species of corals listed and *Beatricea gracilis* Foerste are so far known only in the Lowville limestone, which they characterize from New York to southwestern Virginia, and their presence is sufficient to establish the Lowville age of the beds carrying them in the Bellefonte quadrangle and other areas as far south as Alabama.

RODMAN LIMESTONE

Character and thickness.—Overlying the Lowville is a thin but persistent and very distinctive bed which has been named by Butts [21] the " Rodman limestone ", from Rodman station, about a mile north of Roaring Spring, Blair County.

The Rodman is a thin-bedded impure, very fossiliferous limestone. The fragments of fossils, especially the abundant plates of crinoid stems projecting slightly above the surface on weathered layers, give the rock a very characteristic rough granular appearance by which the bed may be identified with a high degree of certainty. The Rodman limestone is a valuable horizon marker because of the characteristics just mentioned and because of its persistence throughout the Nittany Valley region from Bedford County on the southwest to Centre County on the northeast. Furthermore, owing to its impure composition, it is nowhere quarried and almost everywhere marks the top of the quarries in the Lowville limestone in central Pennsylvania. (See pls. 9, *A*, and 10, *A*.)

The Rodman is generally about 30 feet thick.

Fossils and correlation.—The more significant of the Rodman fossils are *Echinosphaerites* of undetermined species and *Plectoceras undatum* (Conrad). Both are rare species. Through the *Echinosphaerites* the Rodman has been correlated with the lower of two beds carrying *Echinosphaerites* in the Chambersburg limestone of Franklin County, Pa.,[22] and through the *Plectoceras* the Rodman is corre-

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[21] Butts, Charles, Geologic section of Blair and Huntingdon Counties, central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 46, p. 525, 1918.

[22] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (no. 170), p. 8, 1909.

lated with the Watertown limestone of Jefferson County, N. Y., which carries the same species and which, like the Rodman in Pennsylvania, immediately overlies the Lowville limestone.

HIATUS BETWEEN RODMAN LIMESTONE AND TRENTON LIMESTONE

If, as believed, the Rodman limestone is to be correlated with the lower of the two beds carrying *Echinosphaerites* in the Chambersburg limestone of the Mercersburg and Chambersburg quadrangles, there is in the Bellefonte area a hiatus between the Rodman and the overlying Trenton limestone represented in parts of the Chambersburg quadrangle by 500 feet of Chambersburg limestone, which there intervenes between the lower *Echinosphaerites* zone and the base of the Martinsburg shale, which in that region represents the base of the Trenton limestone of the Bellefonte region.

TRENTON LIMESTONE

Character and thickness.—Immediately overlying the Rodman limestone is the well-known Trenton limestone, named by the early New York geologists from Trenton Falls, on West Canada Creek between Herkimer and Oneida Counties, N. Y.

The character and thickness of the Trenton at Bellefonte and probably for this entire quadrangle is well shown in the following section measured by Ulrich in 1905:

Section of Trenton limestone along Milesburg road northwest of Bellefonte

	Feet
Reedsville shale with *Triarthrus*.	
Trenton limestone:	
9. Limestone, very shaly or strongly calcareous; shale with *Dalmanella* cf. *D. rogata* (Sardeson)	30
8. Limestone; shaly bands of subcrystalline highly fossiliferous limestone. *Mesotrypa* sp.?, *Dalmanella* cf. *D. rogata* (Sardeson), and *Cryptolithus bellulus* (Ulrich)	20
7. Limestone, thin-layered, argillaceous; shale partings; fossils few	80
6. Limestone; purer layers carry abundant fossils, mainly Bryozoa. *Prasopora* abundant in bottom, associated with *Mesotrypa*, *Nematopora*, *Tetradella subquadrans* Ulrich, and other ostracodes	20
5. Limestone, in part thicker-bedded than any in other parts of Trenton; layers as much as 18 inches thick. *Sowerbyella* (*Plectambonites* of authors) very abundant in bottom, associated with *Rafinesquina* aff. *R. alternata* (Emmons) and *R. deltoidea* (Conrad)	130
4. Shale, calcareous, and shaly limestone in thin layers. *Prasopora* (rare), *Dalmanella* cf. *D. rogata* (Sardeson), *Plectorthis plicatella* (Hall), and small *Sowerbyella*	90

Section of Trenton limestone along Milesburg road northwest of Bellefonte—Con.

	Feet
Trenton limestone—Continued.	
3. Limestone, medium thin-bedded; fossils few	13
2. Limestone and shale similar to no. 4 but more limy in lower half, which is more than half black or dark-gray shaly limestone. Fossils not abundant or good except near top, where such as those of no. 4 occur. Basal 5 feet contains *Homalonotus trentonensis* Simpson and *Sinuites cancellatus* (Hall)	112
1. Limestone similar to no. 2 but even more nearly a pure black limestone. Small *Dalmanella* cf. *D. rogata* (Sardeson), a small *Sowerbyella, Cryptolithus tessellatus* Green?, and fragments of *Isotelus*; the first three begin at bottom and continue higher in bed	60
Rodman limestone.	
	555

In general the Trenton is an evenly thin bedded dark compact or noncrystalline limestone, highly to moderate argillaceous and containing partings of dark shale. On weathering the limestone turns gray on the surface, but the gray color is only a surface film, the body of the rock within being commonly very dark or black. The thin layers are likely to be rather closely jointed, and surfaces underlain by the formation are commonly strewn with small thin rectangular pieces of this characteristic black compact gray-surfaced rock, so that the presence of the Trenton below is plainly disclosed. The even, thin bedding is notable in Blair and Huntingdon Counties southwest of this quadrangle and is equally well developed at Salona, northeast of Bellefonte. (See pl. 10, *B*.)

The thickness of the Trenton, as measured by Ulrich and given in the subdivisions of the preceding section, is 555 feet. A measurement of the thickness of the formation as a whole by Butts at the same place as that by Ulrich, based on the width of outcrop and dip, gave a total of 630 feet.

Distribution and surface form.—The Trenton limestone is mostly covered along the southeast flank of Bald Eagle Mountain, being exposed only in a few places, as north of Waddle and at Bellefonte. There are good exposures along the northwest side and southwest end of the Nittany Mountain syncline, where the formation in several places appears in prominent ridges or knobs. It is, however, covered along the southeast side of Nittany Mountain. There is a wide area and good exposures south of Linden Hall, where the Trenton and Lowville limestones form a prominent ridge, and good exposures on the flank of Tussey Mountain, southeast of Boalsburg, where fossils are plentiful. Farther west toward Shingletown, however, the formation is all covered.

The Trenton limestone weathers to a fertile soil, leaving few large fragments but an abundance of small fragments of rock on the surface.

Fossils and correlation.—Next to the Rodman limestone, the Trenton is the most highly fossiliferous formation of the Ordovician in this region.

From collections submitted to Ulrich, the following species have been identified: From a bed 105 feet above the good quarry bed at the White Rock quarries at Pleasant Gap, just east of the quadrangle, *Schizotreta* sp., *Dalmanella* cf. *D. rogata* (Sardeson), *Rafinesquina* aff. *R. alternata* (Emmons), *Sowerbyella* sp., *Spyroceras* cf. *S. olorus* (Hall), and *Isotelus* sp. Ulrich considers this fauna lower Trenton. On the south side of Nittany Mountain, between Lemont and Oak Hall, near the base of the Trenton, *Sowerbyella*, *Rafinesquina* aff. *R. alternata* (Emmons), *Dinorthis pectinella* (Emmons), *Strophomena* cf. *S. billingsi* Winchell and Schuchert, and *Parastrophia* cf. *P. scofieldi* (Winchell and Schuchert) were obtained. These also indicate a lower Trenton horizon. Near the top of the Trenton in the same locality as the last were collected *Prasopora orientalis* Ulrich, *Mesotrypa* sp., *Eridotrypa* cf. *E. trentonensis* (Nicholson), *Bythopora* sp., *Stictoporella* sp., *Dalmanella* cf. *D. rogata* (Sardeson), *Rafinesquina* sp., *Tetradella* cf. *T. subquadrans* Ulrich, and *Cryptolithus tessellatus* Green. Regarding this faunule, Ulrich states that although *Cryptolithus* is usually characteristic of lower Trenton, some of the characteristic lower Trenton Bryozoa generally found with *Cryptolithus* are lacking here, and this may be a recurrence of that form, which is very abundant in the upper portion of the Trenton in this quadrangle.

From the species listed above a marked similarity is recognized between this formation and the Trenton in New York and elsewhere, and it seems to be properly regarded as typical Trenton. It is possible, however, that the lower 70 feet of the Trenton, at the top of which occurs *Homalonotus trentonensis* Simpson (see preceding section), is older than the Trenton of New York, in which that fossil does not occur. This possibility is strengthened by the additional fact that another fossil, *Parastrophia hemiplicata* (Hall), which occurs near the base of the Trenton in New York, occurs at Salona, northeast of Bellefonte, only above the bed carrying *H. trentonensis*

It is of further interest that *Homalonotus trentonensis* is hardly if at all distinguishable from *H. bisulcatus* Salter of the Caradoc beds of England, from which the approximate equivalence of the Trenton and Caradoc may be inferred.[23]

REEDSVILLE SHALE

Character and thickness.—Without any marked physical break the shales in the top of the Trenton grade upward into a thick formation of brown, greenish, and black clayey to sandy shales, which has been named by Ulrich [24] "Reedsville shale," from exposures at Reedsville, Mifflin County, Pa. This shale has been called, in various reports of the Second Geological Survey of Pennsylvania, "No. III," "Hudson River," "Utica," and "Lorraine" shale.

On the mountain side south of Boalsburg, at the west end of Nittany Mountain, and elsewhere the rock in the lower portion is splintery, breaking up into sliverlike fragments. The formation contains limonitic and calcareous concretions which on weathering leave rounded protruding masses, and iron pyrite is present in abundance in many places, causing the rock to weather rusty. Portions of the formation are highly carbonaceous, and in Galbraith Gap it is so carbonaceous and graphitic that it was once prospected for coal. In the upper layers the shale grades into a gray, rust-spotted sandstone, thus showing a transition to the conditions under which the overlying Oswego sandstone was laid down. This is probably the *Orthorhynchula* bed widely distributed in the Appalachian Valley through Virginia and Tennessee.

In the Bellefonte section along the road to Milesburg the lowest beds, which are the only ones exposed, consist of very thin brown to black shale, containing *Triarthrus eatoni* (Hall) and *Diplograptus*. On account of the poor exposure of the formation it is impossible to obtain an exact measurement of the thickness in this locality, but as careful a measurement as could be made gave about 900 feet.

A section in which a good portion of the formation is exposed was measured at the village of Buffalo Run, in Bald Eagle Mountain. The strike is N. 55° E. and the dip practically vertical. The upper contact is not exposed, but the following section was obtained by measuring downward from the supposed line of contact.

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[23] Whitcomb, Lawrence, New information on *Homalonotus trentonensis*: Geol. Soc. America Bull., vol. 41, pp. 341–350, 1930.

[24] Ulrich, E. O., Geol. Soc. America Bull., vol. 22, pl. 27, 1911.

Section of a portion of the Reedsville shale at Buffalo Run

	Feet
Oswego sandstone:	
Reedsville shale:	
Covered with debris from the mountain	81
Greenish-gray slate, grading into and interbedded with brown, irregularly fractured sandy shale. Layers are generally an inch or more in thickness and contain a few fossils	48
Not exposed	42
Dirty-brownish, slightly fossiliferous shale with beds of fine-grained calcareous dark-gray to nearly black sandstone about 6 inches thick	45
Not exposed	22
Arenaceous grayish-brown soft shale with very irregular fracture, becoming more massive than overlying layers. The parting planes are stained purplish black with iron hydrate, and there is a little muscovite. Some thin beds are full of crinoid stems	182
Not exposed	405
	825

From field evidence the total thickness of the formation here is 825 feet, and the lower 405 feet, not exposed, apparently contains the black, almost nonfossiliferous shale seen at several other localities in the quadrangle.

In the Hollidaysburg and Huntingdon quadrangles and in other parts of Pennsylvania there is a thick-bedded sandy and calcareous top member of the Reedsville, 50 feet or more thick, carrying a typical middle Maysville fauna, including *Orthorhyncula linneyi* (James), *Byssonychia radiata* (Hall), and other pelecypods. This member of the Reedsville has not certainly been found in the Bellefonte quadrangle. It is, however, of considerable thickness at Tyrone, about 15 miles to the southwest, and its extension into this quadrangle is hardly to be doubted.

Distribution and surface form.—The Reedsville crops out at the base and on the slopes facing the anticlinal valleys along all the mountains in the quadrangle. As it is moderately resistant to weathering it readily disintegrates, so that exposures are common only along the flanks of mountains where it is protected by the immediately overlying resistant Oswego sandstone. Small exposures may be found along the roads in nearly all the gaps. Only a small exposure is present in the gap at Milesburg and none in the next gap to the east, but there are fairly good exposures in the gap 1 mile northwest of Fillmore, in the Buffalo Run Gap, in Galbraith Gap, and at the southwest end of Nittany Mountain.

The Reedsville crops out on the relatively smooth but steep middle slopes of the mountains and yields a clay soil, which in many places contains too much iron or is too acid for agricultural uses.

Fossils and correlation.—Besides *Triarthrus eatoni* (Hall), found near Bellefonte, the following species, identified by Ulrich and Butts from material collected by Moore at the village of Buffalo Run, occur in the Reedsville shale:

Bryozoan suggesting Stictoporella flexuosa (James). (E)
Pholidops cincinnatiensis (Hall). (E, L, M)
Pholidops subtruncata (Hall). (L)
Dalmanella emacerata (Hall). (E, L)
Dalmanella multisecta (Meek). (E, L)
Sowerbyella rugosa (Meek). (E, L)
Rafinesquina aff. R. alternata (Emmons). (E, L, M)
Zygospira modesta var. (Hall). (E, L)
Ctenodonta pectunculoides (Hall). (E, L, M)
Lyrodesma cincinnatiense (Hall). (E, L)
Modiolopsis sp.?
Sinuites sp.?
Lepidocoleus jamesi (Hall and Whitfield). (E, L, M)

Most of the fossils of this list (those designated by the letter E) are characteristic of the Eden shale of southwestern Ohio and are extensively distributed in beds of that age southeastward into Virginia and eastern Tennessee. They are also characteristic of the lower Loraine beds (Frankfort and Pulaski shales) of New York (designated by the letter L), which are correlated with the Eden. Only four species (those marked M) occur in the Maysville of Ohio. *Pholidops subtruncata* is the only fossil of the list that is not recorded from beds as old as Eden. The greater part of the Reedsville of the Bellefonte quadrangle is therefore equivalent to the Eden of southwestern Ohio and to the Frankfort and Pulaski shales of New York. If *Orthorhynchula* is present in the quadrangle in addition to *Pholidops subtruncata*, it would further indicate that the Maysville group, which overlies the Eden, is also represented in the Reedsville shale.

OSWEGO SANDSTONE

Character and thickness.—The Oswego sandstone was named by Vanuxem[25] from the vicinity of Oswego, N. Y., under the form "Gray sandstone of Oswego." In this quadrangle the Oswego is a nonfossiliferous formation of arkosic sandstone and conglomerate. It is well cemented, very tough and resistant, and brown to gray, with some reddish beds. The gray portion generally turns brownish and becomes spotted on weathering, owing to the oxidation of fer-

[25] Vanuxem, Lardner, Geology of New York, pt. 3, p. 67, 1842.

rous iron. A little pyrite occurs locally. The sand grains are rather angular. The conglomerate contains great numbers of angular black, brown, and reddish shale pebbles, which appear to have a local origin, mostly from the shales of the Oswego but probably in part from the Reedsville beneath. Besides these angular fragments of shale, large quantities of well-rounded white quartz pebbles, as much as 1½ inches in diameter, are irregularly distributed throughout the basal beds. There are also a few jasper pebbles and well-rounded pebbles of sandstone similar to the main sandstone matrix of the formation and also pebbles of coarse and rather loosely cemented sandstone 3 inches or less in diameter, strongly resembling material which might have dried on an exposed river bed. One pebble was found which was very similar to a fine-grained gray gneiss, characteristic of the pre-Cambrian rocks in certain areas. The proportion of pebbles in the conglomerate is very irregular, and in some localities a diligent search is necessary to find any. The formation is extensively cross-bedded in regular and also lenslike form, and some shaly beds are ripple-marked.

The thickness of the formation is 571 feet if measured from the base to the first red shales. However, if the measurement is carried to the point where the red beds really become predominant, the thickness is 838 feet.

It is very difficult to separate sharply the Oswego from the Juniata above, and in fact it is quite impossible to do so in the absence of a fully exposed section, because there are gray sandstones in the Juniata and red shales in the Oswego, and it is often a question as to which is predominant. As a result of such conditions, determinations of the thickness are likely to vary considerably in different parts of the quadrangle.

Distribution and surface form.—The southeastern ridge of the double-crested Bald Eagle Mountain, the V-shaped crest of Nittany Mountain, and Bald Knob of Tussey Mountain are due to the upturned resistant Oswego sandstone. Although the ridge named "Tussey Mountain" in the southeast corner of this quadrangle and in the southwest corner of the next quadrangle to the east is made by the Oswego sandstone, the main part of Tussey Mountain, south of this quadrangle, is made by the Tuscarora sandstone, which makes the flat-topped knob marked by the Flat Top fire signal tower. A narrow ridge extends from the flat-topped knob westward just south of the quadrangle boundary and nearly parallel to it and unites with Tussey Mountain half a mile south of the boundary and half a mile east of meridian 40°50′. Thence southwestward the Tuscarora sandstone forms the narrow Tussey Mountain and the Oswego makes the elongated knobs or shoulders on its northwest slope for a distance of 400 feet below its crest. In Bald Eagle Mountain the strata stand almost vertical; in the other mountains the dip is generally about 40°. The lower dip of the formation in Nittany Mountain and in the vicinity of Bald Knob is also the cause of the wide outcrop of the formation in those parts of the quadrangle. The increasing angle of dip along the strike northeast and southwest of Bald Knob accounts for the narrowing of the outcrop of the formations in those directions. The best exposure is in the gap at Milesburg, where several very small faults cut the formation; good exposures occur also in Shingleton, Galbraith, and McBride Gaps. As a rule, exposures of solid rock are scarce along the crest and slope of the mountains because the formation breaks down into great masses of talus and produces a barren and rough surface.

Fossils and correlation.—The Oswego sandstone is unfossiliferous in central Pennsylvania, where it immediately overlies the *Orthorhyncula* zone at the top of the Reedsville shale. (See p. 44.) As the *Orthorhyncula* zone occupies a position in and near the top of the Fairview, the lower formation of the Maysville group of the Cincinnati region, the beds identified as Oswego sandstone in this quadrangle are definitely younger than the Fairview formation. At Oswego, N. Y.—the type locality—the Oswego sandstone, including therein fossiliferous sandy beds of transitional character at the base, referred by Ruedemann [26] to the Oswego, directly overlies beds referred by the same authority, as also, though somewhat indefinitely, by Ulrich and Foerste,[27] to the middle Maysville—that is, beds equivalent to the Fairmount member of the Fairview formation. In addition, the Oswego sandstone at Oswego is directly overlain by the Queenston formation, and the sandstone here described is directly overlain by the Juniata formation, which is known to be the equivalent of the Queenston through tracing of both into the Richmond group. Furthermore, in Ohio the McMillan, the upper formation of the Maysville group, occupies exactly the same stratigraphic position as the Oswego sandstone of New York and of the sandstone here described—above the Fairview and below the Richmond. Hence the sandstone here described is identified as Oswego and correlated broadly with the McMillan formation of the Cincinnati region.

JUNIATA FORMATION

Character and thickness.—The Oswego sandstone grades upward, commonly by almost imperceptible changes, into a bright to dull red shale and sandstone formation. This formation is known in

[26] Ruedemann, Rudolf, The Utica and Lorraine formations of New York; pt. 1, Stratigraphy: New York State Mus. Bull. 258, pp. 138–148, 1925.
[27] Idem, various passages.

Pennsylvania as the "Juniata", because of excellent sections on the Juniata River in Huntingdon and Blair Counties. It consists of alternating layers of red shale and sandstone with thin beds of medium-fine gray sandstone. In small areas the red sandstone, which has a cement of hematite, is sufficiently durable to make a good building stone, but most of it is comparatively soft and tends to crumble. Considerable mica is present in much of the formation, and some beds contain great numbers of pebbles of reddish and dark shale. These pebbles are not limited to the basal portion of the formation, although they are more prevalent in the lower beds than higher up, and they evidently have their origin, in most places at least, in the broken-up beds of the Juniata itself. As a rule the rocks are cross-bedded, and some are ripple-marked and sun-cracked. No fossils have been found in this formation.

It is difficult to find a section in the quadrangle where the whole formation is exposed and where the thickness may be measured with accuracy, but the section in the gap at Milesburg is almost complete and much the best in the quadrangle. The thickness at this point seems to be about 490 feet, but generally throughout the quadrangle it can hardly be much less than 1,000 feet.

Distribution and surface form.—Because it is much less resistant than the underlying Oswego sandstone and the overlying Tuscarora quartzite, the Juniata forms valleys between the double crests of Bald Eagle and Tussey Mountains. Streams almost invariably cut across the strike of the Oswego sandstone but follow the strike of the Juniata, a notable example of which occurs at the head of Buffalo Run one-third of a mile northwest of Buffalo Run post office. Springs occur near the contact between the two formations. The rock weathers so as to leave rolling hills with a scarcity of good exposures, but with the presence of the Juniata below unfailingly indicated by red soil, which makes good farming land, so that the high ridge slopes and tops are commonly cleared and cultivated. Where not cleared, these areas support a fine forest growth.

Correlation.—The Juniata in the Bellefonte quadrangle seems to be entirely nonfossiliferous, and it can be correlated only on lithologic and physical grounds. It may be regarded as identical in position and physical character with the Juniata elsewhere in Pennsylvania and also as equivalent to the Queenston shale of southwestern Ontario and western New York. The Queenston is known by continuous tracing northwestward through the Great Lakes region to be the eastern equivalent of the highly fossiliferous Richmond shales and limestones of southwestern Ohio and southern Indiana. The Juniata is also continuously traceable southwestward through Virginia, where, in the extreme southwestern part, fossiliferous layers of impure limestone carrying the Richmond faunas occur in it from bottom to top.

Though the Richmond group and its equivalent Juniata formation are classed as Ordovician by the United States Geological Survey, it is proper to state here that the equivalent Queenston (†Red Medina) of New York has always been classed as Silurian by the geologists of New York Geological Survey, and that Ulrich [28] believes, and supports his belief by very convincing reasons, that the boundary between the Ordovician and Silurian should be established according to locality at the base of the equivalent Richmond, Queenston, and Juniata stratigraphic units. The Canada Geological Survey, however, and most other geologists have classified the Queenston as of Ordovician age.

SILURIAN SYSTEM

In this quadrangle the Silurian system is represented by the Tuscarora quartzite, the Clinton formation, and several formations of the Cayuga group, including the McKenzie limestone, the Bloomsburg shale, the Wills Creek shale (restricted), and the Tonoloway limestone, making a total thickness of about 2,000 feet. The Clinton formation and the Cayuga group crop out only on the steep northwest slope of Bald Eagle Mountain in this quadrangle and are almost entirely unexposed, so that full knowledge of them is to be had only from their exposures in Blair and Huntingdon Counties.

TUSCARORA QUARTZITE

Character and thickness.—The Tuscarora quartzite is the same as the †White Medina of early reports on the geology of Pennsylvania and other States to the south, but that name has been discarded for Darton's name " Tuscarora ",[29] taken from Tuscarora Mountain, Pa., a long ridge between Juniata and Perry Counties, 36 miles southeast of Bellefonte.

The Tuscarora is a white to gray sandstone, locally with reddish layers at the top. It ranges in texture from a coarse-grained, loosely cemented, almost conglomeratic rock to a fine-grained, firmly cemented quartzite. The sand grains are usually rather angular, and there are fragments of angular to well-rounded shale in the rock. These pebbles are rather widely distributed through the sandstone in both lateral and vertical directions, and associated with them are small concretions of limonite. Both pebbles and concretions weather out and leave holes, many of which resemble the casts of fossils, but

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[28] Ulrich, E. O., Relative values of criteria used in drawing the Ordovician-Silurian boundary: Geol. Soc. America Bull., vol. 37, pp. 279–348, 1926.

[29] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Franklin folio (no. 32), 1896.

no fossils except *Arthrophycus* have been found. Iron ranges from a trace to more than 3 percent, and the rock is in many places surficially stained a vermilion-red by hematite, which is probably in a colloidal condition. Cross-bedding is a characteristic feature of this formation, and ripple marks also occur in places. The rock usually breaks up on weathering into a great number of small blocks.

In the Milesburg Gap the quartzite has been quarried to a considerable extent for ganister. Near the quarry small amounts of barite are found in narrow fissures. An irregular vein associated with clay gouge and barite in the same locality contains some sphalerite and argentiferous galena. A drift has been opened on this deposit but without promising results.

A fairly good section of the Tuscarora can be measured in the Milesburg Gap, although neither the top nor the base of the formation is exposed. The thickness is about 495 feet, the dip being 75°-90°.

Distribution and surface form.—The northwestern, even-topped ridge of Bald Eagle Mountain, with scarcely a gap of importance in this quadrangle except the one at Milesburg, is occupied by the outcrop of the nearly vertical Tuscarora quartzite. The Tuscarora also caps the high knob in the southeast corner of the quadrangle, where, owing to the resistant character of the quartzite, the second highest altitude in the quadrangle is attained. On account of its jointing and the undercutting of the less resistant Juniata, the Tuscarora breaks down readily into angular blocks, so that the northwest side of Bald Eagle Mountain is covered with slide rock of considerable thickness composed entirely of boulders. These white patches of slide rock, just below the crest of the ridge and nearly destitute of vegetation, are conspicuous and striking to the traveler along Bald Eagle Valley.

Fossils and correlation.—The rock in the Bellefonte quadrangle is similar to that in the corresponding deposits in other parts of Pennsylvania, Virginia, and New York, and there can be no doubt that the formation here considered is correctly identified as the Tuscarora. The only definite fossil found is *Arthrophycus alleghaniensis* (Harlan), and although very poor specimens of this fossil were found in this quadrangle, a fine specimen was found in the same formation at Mill Hall, a few miles east of the quadrangle. Two specimens found in talus blocks on Bald Eagle Mountain showed structures strongly resembling *Daedalus archimedes* (Ringueberg), fine specimens of which occur in boulders of the Tuscarora at Tyrone, to the southwest. In New York these forms are confined to the upper part of the Albion sandstone, which is the upper 120 feet or so of the old Medina group of New York.[30] It seems probable that the Tuscarora includes the equivalent of the Albion if it is not the thickened full equivalent of that formation.

CLINTON FORMATION

Character and thickness.—The description of the Clinton formation in the Bellefonte quadrangle must be based on a small outcrop in the gap at Milesburg and another in the gap south of Curtin, which is just east of the quadrangle boundary. The formation extends all along the northwest flank of Bald Eagle Mountain but is rarely exposed. Here and there, however, a few fragments of green shale in a road cut reveal the presence of the Clinton below the surface. One small piece of "flaxseed" iron ore, unknown in the region except in the Clinton, was found on the mountain side south of Julian.

The outcrop near Milesburg, on the west side of the creek, opposite the charcoal furnace, shows in vertical strata 70 feet of dirty-green thin-bedded soft shale with a few sandy streaks. On the east side of the creek, at about 190 feet from the top of the Tuscarora, there is an outcrop of very soft dirty-green and yellow shale, 55 feet in width, with one thin fossiliferous layer. In general the Clinton of Nittany Valley is composed almost wholly of shale such as that exposed at the places just described. Locally thin layers of fine-grained greenish sandstone occur at different horizons in the formation, and it also contains a few thin layers of impure limestone, mostly in the upper part. Fossil ore, such as occurs in the Clinton in other parts of Pennsylvania, has not been found in the Bellefonte quadrangle, though its presence in some thickness may be assumed from the fact that a thin bed occurs at Howard, about 12 miles along the strike of Bald Eagle Mountain northeast of Milesburg.

It is impossible to determine with accuracy the boundaries and thickness of the formation in this quadrangle, because of inadequate exposures. In Blair and Huntingdon Counties, where the conditions for determination are better, the thickness is somewhat more than 800 feet, and it probably does not differ greatly from that amount in this area.

Distribution and surface form.—The Clinton crops out all along the northwest side of Bald Eagle Mountain, where its base extends high on the sides of the mountain, as proved by a fragment of shale or "flaxseed" ore here and there. From Tyrone, 20 miles southwest of Julian, the Clinton and immediately underlying Tuscarora quartzite can be traced continuously along the crest and west slope

[30] Kindle, E. M., U. S. Geol. Survey Geol. Atlas, Niagara folio (no. 190), p. 6, 1913.

of Bald Eagle Mountain into and across the Bellefonte quadrangle and beyond to the vicinity of Williamsport, northeast of the quadrangle. The only exposures found in the quadrangle are in the Milesburg Gap along Spring Creek. The best exhibition of the formation in this belt of outcrop is in the vicinity of Hollidaysburg, where the lower part is exposed near the old Frankston ore mines, at the southeast end of Brush Mountain, and the upper part with thin ferruginous limestone layers is exposed in the streets of the town and also especially well exposed along the highway opposite Lakemont Park. The succession from the Tuscarora into the Clinton crops out at the west entrance of Kettle Gap, about 2 miles east of Altoona. Such exposures are very rare. Between Lock Haven and Williamsport other good exposures of the Clinton occur.

Fossils and correlation.—The few fossils listed below were obtained from the Clinton in the shale exposure east of Spring Creek in the Milesburg gap, about 190 feet above the bottom of the formation. They were identified by Ulrich and Butts.

Cleidophorus sp.?
Chonetes cf. C. novascoticus Hall.
Two undescribed species of pelecypods.
Mastigobolbina lata (Hall).
Mastigobolbina vanuxemi Ulrich and Bassler.
Zygobolbina conradi Ulrich and Bassler.
One new species of ostracode.
Fragments of trilobites.

According to Ulrich, the ostracodes of this list indicate the middle Clinton zone, which he has been able to distinguish throughout the Appalachian region from New York to northern Georgia. The upper 50 to 60 feet of the Clinton with the limestone layers as described above is also known to be of the age of the Rochester shale of the Niagara Gorge section in New York. It is also well enough known from all the circumstances that the formation here described is the same as that of other parts of Pennsylvania demonstrated by abundant fossil evidence obtained in the Hollidaysburg region to be the equivalent of the typical Clinton of New York, which also includes the equivalent of the Rochester shale.

The results of exhaustive studies of the Clinton faunas of the Appalachian Valley made by Ulrich are published by the Maryland Geological Survey in the volume on the Silurian system in Maryland.

HIATUS BETWEEN CLINTON FORMATION AND McKENZIE LIMESTONE

As no representative of the Lockport dolomite, the youngest division of the rocks of Niagara age, is recognized in the Bellefonte quadrangle and that formation is probably absent, there is a slight hiatus between the Clinton formation and the immediately overlying McKenzie limestone, the basal formation of the Cayuga group.[30a]

CAYUGA GROUP

Between the Clinton formation and the Helderberg limestone occur four formations of the Cayuga group. Here, as in western Maryland and throughout central Pennsylvania, the group includes the McKenzie limestone, the Bloomsburg shale, the Wills Creek shale (restricted), and the Tonoloway limestone, named in ascending order, but in the quadrangle they are not exposed except partially near Milesburg, where they occur in a narrow band in the minor anticline that passes through that place. In this anticline only the upper formation of the group, the Tonoloway limestone, is exposed, but at other points on the northwest slope of Bald Eagle Mountain, as just south of Spring Creek, red soil (Bloomsburg) and fragments of yellowish shale (Wills Creek) on the surface and in the gap south of Curtin just east of the quadrangle small outcrops of the yellowish shale give sufficient evidence of the presence of other formations of the group in this quadrangle.

In different parts of Pennsylvania and in reports of the Second Geological Survey of Pennsylvania these Cayuga rocks have been called "Salina shales" and have been included partly in the Clinton and partly in the Lewistown limestone. In the report on Centre County, according to the columnar and profile sections on the geologic map, the Cayuga formations are included in the Clinton and †Lower Helderberg, which are given a combined thickness of 2,059 feet. Of this thickness the true Helderberg limestone makes up about 150 feet, leaving 1,909 feet for the Clinton and Cayuga. This figure seems somewhat excessive as, even if the beds are vertical, there is hardly room for such a thickness of beds between their fairly well determined top and bottom boundaries. Their total thickness can hardly equal or exceed 1,800 feet, and if 800 feet is allowed for the Clinton, the Cayuga formations would be 1,000 feet thick. This is somewhat less than their apparent thickness in Blair and Huntingdon Counties.

M'KENZIE LIMESTONE

Character and thickness.—The McKenzie limestone, named by Stose [31] from McKenzie, a station on the Baltimore & Ohio Railroad west of Cumberland, Md., is not known to be exposed in this quadrangle. It is seen, however, immediately overlying the Clinton at

[30a] It is only fair to say here that there is a difference of opinion on this point. F. M. Swartz is inclined to correlate the McKenzie with the Lockport.

[31] Stose, G. W., and Swartz, C. K., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (no. 179), p. 6, 1912.

Tyrone, on the southwest, and in a gap of Bald Eagle Mountain half a mile southeast of Castanea and about 2 miles southeast of Lock Haven, on the northeast, so its presence in the quadrangle may be accepted. The McKenzie is predominantly a thin-bedded blue fossiliferous limestone but contains some shale partings. The best exposures of the McKenzie in this general region are at Lakemont, midway between Altoona and Hollidaysburg, Blair County, and in a cut on the Pennsylvania Railroad 1,500 feet southeast of Barree station, Huntingdon County. At the railroad cut the succession from the Keefer sandstone member of the Clinton, 10 feet thick, upward through beds of Rochester age, 60 feet thick, and the lower 100 feet or so of McKenzie limestone is fully exposed. At Lakemont the McKenzie is about 200 feet thick, and it may be of comparable thickness in the Bellefonte quadrangle.

Fossils and correlation.—The McKenzie is a fairly fossiliferous formation, some of the limestone layers being crowded with ostracodes, especially with the very minute species of *Kloedenella.* No fossils have been collected from it in the Bellefonte quadrangle, however. It is correlated with the basal part of the Salina or Cayuga group of New York by Ulrich.[32] In his correlation table he places the McKenzie on a level with the Pittsford shale. Swartz [33] notes the close relations of the McKenzie to the Rochester shale below and to the Bloomsburg formation above. It is generally agreed that the position of the McKenzie is near the Niagara-Cayuga contact.

BLOOMSBURG REDBEDS

The Bloomsburg red shale was named by I. C. White [34] from the town of Bloomsburg, Columbia County, Pa. The Bloomsburg was later included as a basal member of the Wills Creek shale, next to be described.[35] In 1931 C. K. and F. M. Swartz [36] treated the Bloomsburg as an independent formation, thus returning to the original usage of White. This usage is now accepted by the United States Geological Survey and has been followed in Guidebook 3 of the Sixteenth International Geological Congress, 1933, and in the map of the Appalachian Valley of Virginia and the accompany-

[32] Ulrich, E. O., and Bassler, R. S., Silurian formations: Maryland Geol. Survey, Silurian, pp. 244–247, 1923.

[33] Swartz, C. K., Geologic relations and geographic distribution of the Silurian of Maryland: Maryland Geol. Survey, Silurian, pp. 206–207, 1923.

[34] White, I. C., Pennsylvania Second Geol. Survey Rept. G7, p. 106, 1893.

[35] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (no. 179), p. 6, 1912. Swartz, C. K., Stratigraphic and paleontologic relations of the Silurian strata of Maryland: Maryland Geol. Survey, Silurian, pp. 40–45, 1923.

[36] Swartz, C. K. and F. M., Early Silurian formations of southeastern Pennsylvania: Geol. Soc. America Bull., vol. 42, pp. 656–660, 1931.

ing explanatory text.[37] The Bloomsburg is not mapped in the Bellefonte quadrangle, but its outcrop occupies a narrow band near the contact of the McKenzie and Wills Creek, as shown by the boundary line between those formations.

Character and thickness.—Owing to poor exposures, but little is known of the Bloomsburg in the Bellefonte quadrangle or along the northwest slope of Bald Eagle Mountain south to Altoona. An occasional show of red soil at its horizon attests its presence, however. Such soil occurs high on the mountain side about 1¼ miles due south of Central City. A few other patches have been noted south to Tyrone and beyond. There are very good exposures between Altoona and Hollidaysburg and southwest of Hollidaysburg, the outcrop passing about half a mile west of Lakemont and in a curve 1½ miles southwest of Hollidaysburg.

The formation in the Altoona-Hollidaysburg region is composed of beds of red and gray shale with perhaps thin layers of limestone. It does not seem to be more than 50 feet thick in that region and probably is no thicker if as thick in the Bellefonte quadrangle. Northeastward from the Bellefonte region it is exposed at the northwest base of Bald Eagle Mountain between Lock Haven and Williamsport, where it can be seen from the railroad cars. It is evidently thicker at these places than in the Bellefonte quadrangle, and its thickness is known to increase to 1,800 feet in eastern Pennsylvania. In the Bald Eagle Valley only the feather edge of the westward-thinning mass is present, and it is not known farther west. In eastern Pennsylvania where thickest it is believed to occupy the whole vertical extent of the Cayuga group from the McKenzie at the base to the Tonoloway at the top.[38] Its relations in the Silurian section are similar to those of the Catskill in the Devonian section, with the difference that the basal beds of the Bloomsburg extend farthest west, whereas the top beds of the Catskill extend farthest west.

Fossils and correlation.—Fossils have not been found in the Bloomsburg in the Bellefonte region, and they are absent or very rare elsewhere. The sediments of the formation evidently accumulated under nonmarine conditions. The Bloomsburg of central Pennsylvania has been satisfactorily traced into the lower part of the thick Bloomsburg of eastern Pennsylvania, and there is general agreement that it corresponds to the red Vernon shale of northwestern New York, which is overlain by the Camillus shale, which seems to be closely similar to the Wills Creek shale overlying the Bloomsburg, as described under the next head.

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[37] Geologic map of the Appalachian Valley of Virginia, with explanatory text: Virginia Geol. Survey Bull. 42, p. 26, 1933.

[38] Swartz, C. K. and F. M., op. cit., pp. 656–660.

WILLS CREEK SHALE (RESTRICTED)

Character and thickness.—The Wills Creek shale was named by Stose [39] from Wills Creek, near Cumberland, Md. As defined, the formation included at the base the red Bloomsburg shale, but the name is now restricted [40] to the light-colored shales overlying the Bloomsburg shale and underlying the Tonoloway limestone. Along the northwest foot of Bald Eagle Mountain there may be found here and there a patch of strongly colored red soil, below which topographically (but above it stratigraphically) are small fragments of a yellowish calcareous shale, although no exposures occur within the quadrangle. In the gap south of Curtin there are fragments of this yellowish shale. The lithologic character and the sequence of the beds indicated by these surficial exhibits are so similar to those of the Wills Creek and Bloomsburg shales in the Hollidaysburg quadrangle that there seems to be no doubt that the yellowish calcareous muddy shale represents the Wills Creek formation as now restricted.

As known from exposures in Blair and Huntingdon Counties, most of the Wills Creek shale is, in the fresh unweathered condition, a compact calcareous clay rock of bluish-gray color. Locally, thin layers of fairly pure coarsely crystalline limestone occur. On weathering the clay rock breaks down to a yellow-green shale, mostly taking the form of small, thin flakes, such as can be seen abundantly mixed in the soil overlying the Wills Creek area in the vicinity of Hollidaysburg, Blair County, and of Alexandria, Huntingdon County, and elsewhere.

The exact thickness of the Wills Creek cannot, under the conditions of exposure, be determined, but it is probably about 400 feet.

Fossils and correlation.—Fossils have not been found in the Wills Creek shale in the Bellefonte region, and they are scarce everywhere in central Pennsylvania, but such forms as *Leperditia alta* (Conrad) occurring in the Wills Creek elsewhere [41] point to its correlation with the Camillus shale of New York. This correlation is supported by the lithologic similarity or even identity of the Wills Creek shale with the Camillus shale of similar character, overlying the Vernon, and is definitely expressed by Ulrich's correlation tables.[42] The absence, in Pennsylvania, of rock salt, which occurs at the top of the Vernon shale of New York, and of gypsum, which occurs in the Camillus shale, is worthy of note. This condition is discussed further under the heading " Geologic history " (p. 88)

[39] Stose, G. W., op. cit., p. 7.

[40] Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, p. 26, 1933.

[41] Stose, G. W., and Swartz, C. K., op. cit., p. 7.

[42] Ulrich, E. O., and Bassler, R. S., The Silurian of Maryland, pp. 244, 267, Maryland Geol. Survey, 1923.

TONOLOWAY LIMESTONE

Character and thickness.—The Wills Creek shale is succeeded above by the Tonoloway limestone, which was named by Stose from Tonoloway Ridge, in Washington County, Md., and Fulton County, Pa. The character of the Tonoloway is best known from exposures in Blair and Huntingdon Counties, where it is a thin-bedded, rather impure compact dark limestone 500 feet thick. This formation is partly exposed in the section along the railroad track southwest of Milesburg, where it is brought up in a minor anticline, and also along the crest of this anticline just beyond the eastern border of the quadrangle. Where this anticline crosses the crest of the long spur south of Central City, abundant small pieces of the characteristic thin-layered dark compact limestone of the Tonoloway are scattered on the surface. It may be regarded as about 400 feet thick.

Fossils and correlation.—The Tonoloway limestone has yielded many fossils in Maryland, from the study of which Ulrich concludes that the formation is of late Cayugan (post-Salina) age and includes the equivalent of the lower part of the typical Manlius limestone and of the Cobleskill limestone of New York. A list of the fossils, with Ulrich's discussion, is given by Stose.[43] There are, however, some features of the faunas of the Cobleskill and Manlius that throw doubt on the validity of this correlation.

DEVONIAN SYSTEM

No marked lithologic break occurs between the Tonoloway limestone and the overlying Keyser limestone member of the Helderberg. There is, however, a considerable change in fossils, indicating a change in the animal life between the deposition of the basal Helderberg and that of the Tonoloway, and this may indicate withdrawal of the sea, cessation of sedimentation, and a consequent hiatus. The evidence is not decisive on these matters.

The Devonian system is represented in this quadrangle by formations whose aggregate thickness reaches 7,400 feet, including the Helderberg limestone, the Shriver formation and Ridgeley sandstone of the Oriskany group, the Marcellus shale, the Hamilton shale, the Harrell and Brallier shales of the Portage group, and the Chemung and Catskill formations. The Devonian rocks occupy a single broad belt of hilly country, the foothills of the Allegheny Mountains, extending northeastward across the quadrangle between Bald Eagle Valley and the Allegheny Mountains on the northwest

[43] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Pawpaw-Hancock folio (no. 179), p. 7, 1912.

and between Bald Eagle Valley and the lower part of the northwest slope of Bald Eagle Mountain on the southeast. This belt is 3 miles wide on the southwest and 6½ miles wide in the northeastern part of the quadrangle.

HELDERBERG LIMESTONE

Character and thickness.—"Helderberg" is an old name taken from the Helderberg Mountains, in Albany and Schoharie Counties, N. Y. In this quadrangle the Helderberg is poorly exposed but so far as known consists of alternately thin-bedded shaly and impure limestone and thick-bedded, comparatively pure limestone. For example, in a quarry on the flank of Bald Eagle Mountain, 1¼ miles southwest of Unionville, 30 feet of rock is exposed, of which 10 feet consists of comparatively pure limestone, whereas on both sides of this purer rock there are shaly beds and thin beds of limestone with very distinct shale partings. In places there is a parting of black carbonaceous shale with a seam of clay. In a small abandoned quarry in the hill just west of the railroad track three-quarters of a mile southeast of Milesburg, there is an exposure of gray coralline limestone that is very tough, siliceous, and massive, and distributed through it are a good many chert nodules as well as veinlets and blotches of calcite.

The upper 20 feet or so of the Helderberg generally yields a considerable amount of dense gray fossiliferous chert.

The thickness of the Helderberg limestone is 150 feet, as determined in a section in Curtin Gap, just east of the quadrangle, 2½ miles northeast of Milesburg, where the beds are vertical and well exposed on the limbs of the small syncline and of the small anticline extending northeastward from Milesburg, in which the Helderberg as well as the Oriskany and Marcellus rocks are involved.

Distribution and surface form.—The Helderberg limestone crops out in a narrow band along the northwest foot of Bald Eagle Mountain and its outcrop is repeated on each side of the minor anticline that passes through Milesburg, making three narrow bands at Milesburg. There are reasons for believing that these three bands persist several miles southwest along the slope of Bald Eagle Mountain but that farther southwest only the southeastern outcrop persists. (See p. 62.) Owing to these features of outcrop, which affect the Oriskany formations also, and to the fact that the formations are completely concealed along the slope of Bald Eagle Mountain, so that the details of outcrop cannot be seen, the Helderberg and Oriskany formations are for most of this distance mapped together as Lower Devonian. Small thicknesses of the Helderberg are exposed near the railroad track and on the long spur southwest and west of Milesburg and in a quarry on the flank of the mountain southwest of Unionville. The formation is well exposed about 2½ miles northeast of Milesburg just outside the quadrangle. A little chert remains on the surface in some areas where the limestones have weathered away.

Fossils and correlation.—In general the Helderberg is fairly fossiliferous, *Stromatopora*, corals, Bryozoa, and brachiopods being the most abundant fossils. T. C. Brown identified the following fossils from the abandoned quarry near Milesburg:

Diphyphyllum integumentum (Barrett).
Cladopora rectilineata Simpson.
Cladopora bifurcata Grabau.
Favosites pyriformis (Hall).
Favosites corrugatus Weller.
Halysites catenularia (Linnaeus).
Proetus pachydermatus Barrett.
Proetus spinosus Weller.

In some shale beds a little higher in the formation he found a fauna containing *Leperditia alta* (Conrad), *L. altoides* Weller, *L. elongata* Weller, *L. gigantea* Weller, *L. jonesi* Hall, *Cyathophyllum hydraulicum* Simpson, and *Whitfieldella nucleolata* (Hall).

From the quarry southwest of Unionville and that near Milesburg a large number of fossils were collected among which Ulrich has identified the following species:

Quarry southwest of Unionville

Cladopora rectilineata Simpson.
Striatopora sp.?
Cyathophyllum clarki Swartz?
Favosites pyriformis (Hall).
Stropheodonta bipartita (Hall).
Leptaena rhomboidalis (Wilckens).
Chonetes sp.
Camarotoechia litchfieldensis (Schuchert).
Atrypa reticularis (Linnaeus).
Atrypa spinosa Hall.
Spirifer vanuxemi var. Hall.
Whitfieldella minuta Maynard?
Leperditia cf. L. alta (Conrad).

Quarry near Milesburg

Striatopora sp.
Cladopora rectilineata Simpson.
Cyathophyllum clarki Swartz.
Cyathophyllum radiculum Rominger.
Cyathophyllum schucherti Swartz?
Favosites pyriformis (Hall).
Fistuliporella maynardi Ulrich and Bassler?

From these faunules, and also from that collected by Brown, Ulrich concludes that this limestone is properly regarded as the Keyser member of the Helderberg as recognized in northeastern West Virginia, western Maryland, and southern Pennsylvania. *Cladopora rectilineata* is an especially good marker for the Keyser. The type locality of the Keyser member is at Keyser, W. Va.

The following fossils from the upper part of the Helderberg on the north limb of the small anticline west of Milesburg have been identified by Ulrich, who considers this fauna typical of the New Scotland, the middle division of the Helderberg limestone in the Helderberg Mountains of New York.

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Orthopora ovatipora (Hall).
Orthopora regularis (Hall).
Isorthis perelegans (Hall).
Rhipidomella assimilis (Hall)?
Leptaena rhomboidalis (Wilckens).
Eospirifer macropleurus (Conrad).
Phacops logani Hall.
Dalmanites micrurus (Green).

In New York and generally in Pennsylvania and Maryland the Coeymans limestone member, of small thickness, is present between the Keyser and New Scotland members. It is probably represented in the Bellefonte section but has not been identified.

HIATUS BETWEEN HELDERBERG LIMESTONE AND SHRIVER FORMATION

In New York and Maryland the New Scotland limestone member of the Helderberg is overlain by the Becraft limestone member, which has a maximum thickness of 85 feet in Washington County, Md. In central Pennsylvania no representative of the Becraft has been recognized, so that there appears to be a slight hiatus between the New Scotland member of the Helderberg and the overlying Shriver formation.

ORISKANY GROUP

In the Bellefonte quadrangle, as in western Maryland and southern Pennsylvania, the Oriskany group comprises two formations—the Shriver formation, of limestone, shale, fine-grained sandstone, and chert, and the Ridgeley sandstone. They are not mapped separately in this quadrangle, owing to their small thickness, vertical attitude, and poor exposures.

SHRIVER FORMATION

Character and thickness.—The Shriver formation was named from Shriver Ridge, near Cumberland, Md.[44] The same beds in Huntingdon County, Pa., were called "Stormville shale" by I. C. White, but as that name was applied by him to other units also, its further use is inadmissible.

The character of the Shriver varies greatly from point to point in the quadrangle, and the lithologic variation is commonly great within very short distances. In the section of the railroad at Milesburg it is a rather distinct limestone, somewhat cherty and in the lower portion becoming shaly. On the north limb of the small anticline close to Bald Eagle Creek, where it crosses the eastern boundary of the quadrangle, the formation consists of a gray to black papery shale that grades upward into more limy and thicker shales that are overlain by the Ridgeley sandstone. On the south side of this anticline and also of the small syncline south of it the formation is a very cherty, impure limestone with distinct beds of

[44] Maryland Geol. Survey, Lower Devonian, p. 91, 1913.

chert as much as 6 inches in thickness. This cherty phase of the formation is also well developed along the strike several miles east of the quadrangle.

Distribution and surface form.—The Shriver formation undoubtedly occurs in very narrow bands occupying the surface between the outcrop of the Helderberg limestone and that of the Ridgeley sandstone along the foot of Bald Eagle Mountain throughout the quadrangle, although no exposures of the formation have been found there. It also crops out on both limbs of the small Milesburg anticline. There are good exposures near the eastern border of the quadrangle, and a fair exposure also along the railroad in the south side of this anticline in the vicinity of Milesburg. Here its presence is indicated by small chips of soft yellowish or brownish sandy rock scattered on the surface or embedded in the soil. In these chips the ostracodes named below can usually be found.

Fossils and correlation.—The fossils found in the Shriver formation of the Bellefonte quadrangle are listed below. The identifications are by Ulrich.

Lingula sp.?	Conularia sp.
Orbiculoidea sp.?	Tentaculites elongatus Hall?
Pholidops multilamellosa Schuchert.	Bollia curta Ulrich and Bassler.
Metaplasia plicata Weller.	Bollia n. sp.
Metaplasia, 2 undescribed species.	Thlipsurella n. sp.?

This small fauna has its nearest relatives in the Shriver formation of Maryland and of the Hollidaysburg-Huntingdon region of Pennsylvania, where larger collections of fossils have been made. Of the fauna listed, the Metaplasias are closely related to *Spirifer paucicostatus* Schuchert, from the Shriver of Maryland; the *Pholidops* is a Shriver species; and species of *Thlipsurella* are fairly common in the Shriver of the Hollidaysburg-Huntingdon region.

On the basis of these fossils, therefore, as well as on that of similarity in stratigraphic position and lithology, these rocks in the Bellefonte quadrangle are correlated with the Shriver chert of western Maryland and the Huntingdon and Hollidaysburg quadrangles in Pennsylvania. The Shriver is also correlated with the lower Oriskany Port Ewen limestone of southeastern New York.

RIDGELEY SANDSTONE

Character and thickness.—The Ridgeley sandstone was named from Ridgeley, W. Va.[45] It varies within short distances from an impure, calcareous soft brown sandstone to a pure white coarse-grained sandstone. Probably in this region, as in Blair County, the formation is highly calcareous in the unweathered condition, the

[45] Maryland Geol. Survey, Lower Devonian, p. 92, 1913.

pure sandstone phase seen in outcrop being due to the leaching of the calcium carbonate. Some portions are sufficiently pure to encourage attempts to employ the sand for glass making, but it did not prove to be entirely satisfactory for this purpose. In places the rock is conglomeratic with small pebbles of quartz. The bulk of the sandstone is fossiliferous, in places highly so; and this feature permits its distinction from the Tuscarora and Oswego sandstones, with which fragments of Oriskany sandstone are mixed all along the northwest foot of Bald Eagle Mountain. It also disintegrates more readily than the other sandstones and readily breaks down to loose yellow and white sand and small fragments, which occur on the surface in some areas. The thickness of this formation ranges from 75 to 130 feet.

Distribution and surface form.—In the vicinity of Milesburg there is a wide band of outcrop of the Ridgeley sandstone along and mostly just southeast of Bald Eagle Creek. Two narrow bands pass a short distance southeast of Milesburg, one on each side of the Milesburg syncline. The width of all these bands varies with the attitude of the rocks. In the wide northwest band the dip is comparatively low; in the two narrow southeast bands the beds are vertical. These facts and their effects on the width of outcrop and apparent thickness are shown in structure section A–A′, plate 2. Apparently Bald Eagle Creek tends to follow the outcrop of this formation because it disintegrates rapidly to loose sand that is easily washed away. The Ridgeley, full of fossils, is exposed in the creek beneath the railroad bridge at Central City, in the southeast side of the knoll midway between Central City and Snowshoe Intersection, and in the knoll opposite the valley of Mudlick Run, 2 miles from the west boundary of the quadrangle. There are also excellent exposures just east of the quadrangle, three-quarters of a mile south of Curtin. Although the tendency of this formation is to break down readily, in places it remains as knobs, which as a rule are due to the protection afforded by a body of the cherty limestone that accompanies the sandstone. (See p. 58.)

Fossils and correlation.—The Ridgeley sandstone is highly fossiliferous. The following forms have been identified by Ulrich:

Rhipidomella musculosa (Hall).
Leptostrophia arctimuscula Schuchert?
Leptrostrophia magnifica Hall.
Hipparionyx proximus Vanuxem.
Chonetes sp.
Plethorhyncha speciosa (Hall).
Uncinulus sp.
Eatonia peculiaris (Conrad).
Rensselaeria ovoides (Eaton).
Beachia cumberlandiae (Hall)?
Beachia suessana (Hall).
Oriskania lucerna Schuchert.
Spirifer arenosus (Conrad).
Spirifer murchisoni Castelnau.
Spirifer angularis Schuchert.
Spirifer tribuarius Schuchert.
Spirifer intermedius Hall.
Metaplasia pyxidata (Hall).

Leptocoelia flabellites (Conrad).
Meristella symmetrica? Schuchert?
Meristella sp.?
Actinopteria communis (Hall).
Cyrtolites? expansus Hall.
Platyceras gebhardi Conrad.
Platyceras gracile Ohern.
Diaphorostoma ventricosum (Conrad).
Tentaculites sp.

This fauna, which is typical of the Oriskany sandstone elsewhere, demonstrates the Oriskany age of this formation and, together with similarity in lithology and stratigraphic position, serves to correlate it with the Ridgeley sandstone of western Maryland and the Hollidaysburg and Huntingdon quadrangles of Pennsylvania.

HIATUS BETWEEN RIDGELEY SANDSTONE AND MARCELLUS SHALE

In the Hollidaysburg and Huntingdon quadrangles the Ridgeley sandstone is immediately overlain by about 50 feet of shale and limestone of Onondaga age. This formation has not been detected in the Bellefonte quadrangle and in at least one section is absent, so that the Marcellus shale immediately succeeds the Ridgeley sandstone. If the Onondaga and the underlying Schoharie grit are nowhere present there is a slight hiatus between the Ridgeley sandstone and the Marcelluus shale throughout the quadrangle.

MARCELLUS SHALE

Character and thickness.—The Marcellus shale overlies the Ridgeley sandstone, of the Oriskany group. The name is an old one, from Marcellus, Onondaga County, N. Y. As used in this report it is essentially as applied in past literature of Pennsylvania—that is, it is Marcellus "of authors." Recent work in New York and in parts of Pennsylvania has suggested that a revision of Middle and Upper Devonian nomenclature may be made, but the present work is not sufficiently extensive to supply the data for it.

There are few exposures of the Marcellus shale in the quadrangle. Where exposed it is black or brown, fissile, slaty, and somewhat carbonaceous. In an exposure near the eastern border of the quadrangle sandy and calcareous concretions occur, some of which are fossiliferous. The thickness is estimated at 100 feet.

Distribution and surface form.—Exposures of the Marcellus near the eastern and western boundaries of the quadrangle indicate that a narrow band extends across it along Bald Eagle Creek. Owing to the nonresistant character of the formation it is exposed in but few places, and for considerable stretches it lies under the bed of the creek. There is an exposure near the creek half a mile west of the eastern border of the quadrangle, where the formation is in contact with the Ridgeley sandstone, another on the highway at the northwest base of the low knoll midway between Snowshoe Intersection and Central City, and a small one about 2 miles from the western boundary of the quadrangle at the northwest side of a low knoll opposite the valley of Mudlick Run. In addition, there is an exposure about half a mile south of Milesburg, near the railroad to Bellefonte, and another just at the eastern border of the quadrangle, both of which are situated along the small Milesburg syncline, where the Marcellus has been folded down and partly enclosed by the Ridgeley sandstone. Where the formation crops out it usually leaves rounded knolls covered with fragments of black shale, weathering gray or brownish if much iron is present.

Fossils and correlation.—Few fossils were found in this formation, though Butts has identified the following from the small exposure on the bluff west of Spring Creek half a mile southwest of Milesburg and regards them as typical Marcellus forms. The *Leiorhynchus* is characteristic of the Marcellus of New York. The bryozoan *Paleschara* occurs rarely in the Marcellus to southwestern Virginia.

Paleschara sp.?
Chonetes mucronatus (Hall).
Leiorhynchus limitare (Vanuxem).
Leptalosia truncata (Hall).
Nuculites triquiter Conrad.
Pleurotomaria rugulata Hall.
Styliolina fissurella (Hall).
Goniatites? sp.

HAMILTON FORMATION

Character and thickness.—The Hamilton shale was named from West Hamilton (now Hamilton), Madison County, N. Y. As in the case of the Marcellus shale, the name is used here essentially as in the past, but it is expected that the classification and nomenclature may eventually be revised. There are many good exposures of the upper part of the Hamilton along the north side of the valley of Bald Eagle Creek, but a complete section cannot be found in the quadrangle. The exposed parts of the formation consist of a dirty-brown to yellowish and olive-green shale with bands of black slaty shale including near the top, just beneath the Burket black shale member described on page 66, a 10-foot bed of interlayered fossiliferous limestone and shale, which is persistent in Bald Eagle Valley and farther southwest, at least as far as Altoona. At Lock Haven on the same outcrop the upper part, estimated at 150 feet in thickness, is composed of interbedded limestone and shale. At Altoona the lower part of the formation, not exposed in the Bellefonte quadrangle, includes many layers of even-bedded fine-grained green sandstone. Such layers are probably present in the Bellefonte quadrangle.

A few exposures along the northwest side of Bald Eagle Valley show the following details: At the mouth of the Moose Run gully, above Central City, an outcrop occurs in which there is 10 feet of interbedded gray fissile shale and calcareous rock, grading from almost pure limestone to calcareous shale, the beds ranging from 6 inches to 1 foot in thickness. Near the point where the road crosses the Pennsylvania Railroad track near the east side of Julian is a good exposure that shows calcareous beds followed beneath by thin slaty drab to bluish shale, which is fossiliferous. In an outcrop on the road just beyond the railroad crossing 1½ miles southwest of Julian 20 feet of irregularly fractured, white-weathering calcareous shale is exposed, and beneath it are thin, paperlike layers of black and purple carbonaceous shale. These beds contain many corals, numerous concretions and irregular veins and streaks of pyrite and marcasite, and a few shells replaced by pyrite. These sulphides on weathering produce red and gray spots in the shale.

The thickness of the formation near Milesburg is about 610 feet. and it is about the same near the western border of the quadrangle.

Distribution and surface form.—The Hamilton crops out only along the valley of Bald Eagle Creek, where most of the formation is deeply covered with alluvium. The width of the outcrop differs from place to place, owing to a number of local folds in the formation. Along the north side of the valley there are a good many exposures, which are described in the preceding section. Most of the exposures are on low ground, and the formation generally weathers to a sandy clay soil.

Fossils and correlation.—Fossils are plentiful in the Hamilton shale, especially in the upper calcareous portion. The following species have been identified by Butts:

Lingula cf. L. punctata Hall.
Rhipidomella vanuxemi (Hall)?
Chonetes coronatus (Conrad).
Chonetes mucronatus Hall.
Productella spinulicosta Hall?
Camarotoechia prolifica Hall.
Atrypa spinosa Hall.
Atrypa reticularis (Linnaeus).
Spirifer mucronatus (Conrad).
Spirifer sp.?
Ambocoelia umbonata (Conrad).
Spirifer sculptilis Hall and Clarke.
Tropidoleptus carinatus (Conrad).
Platyceras cf. P. echinatum Hall.
Dalmanites sp.?
Phacops rana (Green).
Proetus rowi (Green).

This list is mainly made up of typical Hamilton forms, and the formation is readily correlated with the Hamilton of New York and other localities.

PORTAGE GROUP

The typical Portage formation of New York was named from Portage Township, Livingston County, within which lies most of the celebrated gorge of the Genesee River, in which the rocks are fully exposed. In central Pennsylvania the Portage rocks have been divided into two formations—an upper thick sandy shale, called the

"Brallier shale", and a lower, much thinner formation, called the "Harrell shale." The basal part of the lower formation has also been named the "Burket black shale member." These three names were given by Butts.[46]

HARRELL SHALE

Character and thickness.—The Harrell shale was named from Harrell station, on the Petersburg branch of the Pennsylvania Railroad in Blair County, Pa. The contact between the Portage group and the Hamilton formation is rather sharply marked by the thin limestone in the upper part of the Hamilton and the densely black fissile shale of the overlying Burket member of the Harrell. The main body of the Harrell consists of gray fissile, somewhat fossiliferous clay shale, distinguished from the overlying Brallier shale by its pale-gray color and softer, clayey composition.

Burket black-shale member.—The Burket member, at the base of the Harrell, 50 to 75 feet thick, is a black carbonaceous slaty shale which cleaves into very thin sheets, commonly paperlike in thinness. It is characterized by a marked jointing that trends N. 35° W. and N. 40° E. In some places there are large calcareous concretions as much as 12 by 20 inches in diameter, many of which contain fragments of fossils replaced by clear spar, although there may be no fossils preserved in the contiguous shale. A little pyrite also occurs in some of the nodules. The member was named for exposures at the town of Burket, a suburb of Altoona. This member of the formation carries but few fossils.

The total thickness of the Harrell shale, including the Burket member, is about 300 feet.

Distribution and surface form.—The Harrell shale occurs only as a band along the northwest side of Bald Eagle Creek at the base of the foothills of the Allegheny Mountains. It weathers more readily than the more resistant sandy Brallier shale and is therefore found on the rounded slopes of the hills, many of which end in sharp ridges due to the outcropping of the Brallier above (pl. 11, *A*).

Fossils and correlation.—Fossils occur sparingly in the Harrell shale. The following were collected by Moore and identified by Butts:

Orbiculoidea lodiensis (Vanuxem).
Buchiola retrostriata (Von Buch).
Pterochaenia fragilis (Hall).
Styliolina fissurella (Hall).
Probeloceras lutheri Clarke.

These can all be regarded as basal Portage forms, and *Probeloceras lutheri* and *Buchiola retrostriata* are noteworthy and constant con-

[46] Butts, Charles, Geological section of Blair and Huntingdon Counties, central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 46, pp. 523–537, 1918.

stituents of the Naples fauna of the Portage of Ontario County, N. Y. The Burket black shale member has usually been regarded as representing the black Genesee shale of western New York, which immediately underlies the Portage formation. None of the most typical of the Genesee shale fossils have been found in the Burket member, but a number of Naples and Cashaqua forms are present in the Burket. It seems most probable that the Harrell, including the Burket member, represents both the Cashaqua shale and the underlying black Middlesex shale of the Portage region, New York. On the basis of lithology and stratigraphic position the formation corresponds to the Harrell shale of the Hollidaysburg and Huntingdon region, the typical area.

BRALLIER SHALE

Character and thickness.—Conformably overlying the Harrell shale is a thick formation of sandy shale which has been named " Brallier shale ", from Brallier station on the Huntingdon & Broad-top Mountain Railroad, in Bedford County, Pa.[47] The Brallier is predominantly a siliceous formation. It is almost wholly made up of a firm green finely and strongly micaceous shale, of which the main constituent is quartz in extremely small grains. This rock in fresh exposures, as in the cuts on the Pennsylvania Railroad a mile or so southeast of Huntingdon, Huntingdon County, commonly appears to be a thick-bedded fine-grained sandstone. On weathering, however, these thick, apparently solid layers of rock break down into thin laminae, owing to the inherent lamination cleavage. On account of this feature the formation is called a shale, although some geologists might prefer to call it a laminated sandstone. The laminae are likely to be crinkled or dimpled and stained a manganese-black or ferruginous red on the surface. The dimpled beds are well displayed in a railroad cut just west of Altoona, photographs of which have been published.[48] In addition to the green siliceous, micaceous shale the Brallier contains minor amounts of clay shale as thin partings and of sandstone in layers generally not over an inch thick.

Distribution and surface form.—This formation extends northeastward across the quadrangle, along the northwest side of the Bald Eagle Valley. Where the more resistant sandstones occur in the basal portion they commonly form a distinct escarpment, rising above the Harrell shale. This escarpment is very prominent southwest of

[47] Butts, Charles, Am. Jour. Sci., 4th ser., vol. 46, p. 523, 1918.

[48] Butts, Charles, The Devonian section near Altoona, Pa.: Jour. Geology, vol. 14, fig. 7, 1906.

Julian and north of Milesburg. Elsewhere the Brallier generally breaks down into rounded shale hills, which show few good exposures except along the runs at their base. Most of these hills are farmed, although many of them are literally covered with fragments of sandstone or shale.

Good exposures may be seen in all the narrow valleys that cross the formation, although probably the most complete is that on Moose Run.

Fossils and correlation.—Scarcely any fossils have been found in the Brallier in the Bellefonte quadrangle, but 26 species, including *Pterochaenia fragilis* (Hall), *Paracardium doris* (Hall), and *Buchiola retrostriata* (Von Buch), have been collected from it by Butts in the Hollidaysburg-Huntingdon region. At least 12 of the 26 species are common forms in the Portage rocks of New York, and a few of them are forms that occur in the Ithaca shale of the Portage of east-central New York. Lithologically the Brallier is practically identical with the Gardeau flags and shale and with the Hatch flags and shale, the thickest formations of the Portage in the type region. The Gardeau also carries, in part at least, the typical Portage or Naples fauna, including most of the Portage forms that occur in the Brallier shale. Probably the Brallier includes a full representative of the Gardeau, the Hatch, and the Nunda sandstone and even of the Wiscoy shale at the top of the Portage of New York. The characteristic lithology and fossils of the Brallier shale persist southwestward to the vicinity of Wytheville, Va.

CHEMUNG FORMATION

Character and thickness.—The Chemung formation was named from Chemung Narrows on the Chemung River, in Chemung County, N. Y. The Portage of the Bellefonte quadrangle is succeeded by a thick formation, consisting of drab, green, brown, and purple shale and shaly sandstone, with a few comparatively thin beds of pure quartz sandstone and conglomerate. These rocks contain a great many fossils throughout, and the upper sandy beds are abundantly fossiliferous. Good exposures occur along the roads all through the Allegheny Mountain foothills, and a very complete section, which was measured in detail, is exposed on Moose Run. The structure is very regular and simple throughout the quadrangle. In the section on Moose Run the strike averages N. 45° E., and the dip is 14°–24° NW., averaging about 20°.

Section of Chemung formation on Moose Run

Catskill formation (red shale).	
Chemung formation:	*Feet*
23. Shale; weathers to a characteristic yellow-green color	50
22. Green, gray, and purple shales, with a few fossils, such as *Camarotoechia* and *Cyrtospirifer disjunctus* (Sowerby)	160
21. Greenish thin-bedded micaceous shale with crinoid stems	23
20. Purple shale	32
19. Greenish to gray and drab shales, with here and there a yellowish and reddish bed	35
18. Yellowish disintegrated shale, highly fossiliferous, with *Camarotoechia contracta* (Hall) and *C. eximia* (Hall)	33
17. Purple beds without fossils	68
16. Purple and rotten brown shale. The brown beds are highly fossiliferous, with *Cyrtospirifer disjunctus* (Sowerby) abundant	80
15. Gray to brown and reddish arenaceous shale with a few thin purple beds, all weathering to drab and yellow. The brown beds are highly fossilferous and contain *Schuchertella chemungensis* (Conrad), *Camarotoechia contracta* (Hall), *Atrypa spinosa* (Hall), *Atrypa spinosa* (Hall), *Crytospirifer disjunctus* (Sowerby), *Delthyris mesicostalis* (Hall), and *Pterinopecten suborbicularis* (Hall)	134
14. Gray and reddish thin-bedded shale with greenish and brownish streaks, the latter fossiliferous, containing *Cyrtospirifer disjunctus* (Sowerby), *Camarotoechia eximia* Hall?, *Cryptonella eudora* Hall?, *Leptodesma lichas* Hall, and *L. potens* Hall?	42
13. Drab shale, with beds of partly decomposed dark-brown iron-stained shale and thin beds of brown calcareous material, with a 5-inch highly fossiliferous bed that carries fossils like those listed under no. 14	38
12. Compact gray and brown thick- to thin-bedded shales interbedded with reddish-brown and brownish-gray partly decomposed shales. The partly decomposed beds contain thin dirty-green highly fossiliferous beds. The thick beds have a very irregular jointing. Fossils as listed under no. 14	230
11. Bed of very coarse, porous, partly disintegrated fossiliferous sandstone, 6 inches thick, underlain by reddish-brown sandy shale containing small fragments of bluish-gray shale	6

Section of Chemung formation on Moose Run—Continued

	Feet
Chemung formation—Continued.	
10. Interbedded gray, brownish, and drab shales and gritty sandy beds with fragments of a thin-bedded conglomerate containing well-rounded quartz pebbles as much as one-fourth inch in diameter. Bluish, opalescent quartz pebbles are common, in a matrix of brownish sandstone	157
9. Dirty-brown and drab shale with a few fragments of conglomerate but none in place	175
8. Interbedded dark grayish-brown dense shale and massive yellowish, greenish, and grayish shale with a dark streak of iron oxide along cracks; fossiliferous	15
7. Gray and greenish shale with fragments of conglomerate	65
6. Gray, greenish, and highly fossiliferous bluish shale	260
5. Brown and gray shale with thin bed of nearly pure white sandstone	145
4. Gray and dense calcareous shale with gray and yellowish sandy shale; some beds highly fossiliferous	215
3. Drab, gray, and brownish rotten shale with dark bands high in iron and all the parting planes stained bluish black. The brownish beds are very fossiliferous	410
2. Gray to drab shale, weathering brown, finely laminated; apparently fucoids but no other fossils	80
1. Thin-bedded, finely laminated slaty shale, weathering with a purple film or a whitish clay deposit along cracks. A few sandy brown beds and iron-gray finely laminated shales with a few fossils such as *Camarotoechia contracta* Hall	270
	2, 723

From beds 3 to 12 of the above section, including a thickness of 1,678 feet, the following faunule was obtained, and similar fossils are plentiful almost throughout the section.

Leptostrophia perplana var. nervosa (Hall).
Chonetes scitulus Hall.
Productella lachrymosa (Conrad).
Schizophoria impressa (Hall).
Camarotoechia contracta (Hall).
Camarotoechia eximia (Hall)?
Leiorhynchus mesacostale (Hall).
Atrypa aspera (Schlotheim) or A. hystrix Hall.
Delthyris mesacostalis (Hall).
Ambocoelia umbonata (Conrad).
Leptodesma sp.
Edmondia subovata Hall.
Tentaculites sp.

This section is characteristic of the Chemung in this quadrangle. The upper portion of the formation consists of greenish shales that are underlain by about 1,000 feet of rock characterized by many rather striking bands of purple or chocolate-brown shale and thin-bedded sandstone. These reddish beds may be located in many places by the characteristic purplish soil which they produce. They can be distinguished from the Catskill red beds by a dull purplish or chocolate-brown instead of a bright brick-red color and by the presence of abundant fossils in them and in the beds of different color associated with them. There are also, in the upper portion of the formation, thin beds of impure, highly fossiliferous limestone. The conglomerate beds mentioned in the section are also a distinctive feature. The conglomerate occurs as fragments on Antis, Moose, and other runs, apparently derived from the disintegration of thin beds distributed through several hundred feet of rock, but on Dewitt Run there is a 4-foot bed at one point and a number of thin beds several hundred feet farther up the run. Although there are apparently several thin conglomeratic layers, the conglomerate here, as in the Hollidaysburg and Tyrone quadrangles, is probably confined mainly to a single bed near the middle of the formation, not far below the lowest of the purple or chocolate-brown beds. The high knobs extending as a chain across the quadrangle near the middle of the Chemung band are not improbably associated with the outcrop of this conglomerate. Beds of white sandstone like those in the section on Moose Run may also be found at several other places in the quadrangle. A good example of white sandstone occurs along the road 1½ miles northeast of Belleview School.

Sun cracks and ripple marks are fairly common in the formation, but they are not so prominent as in the overlying Catskill formation.

Distribution and surface form.—Owing to its gentle dip and great thickness, the Chemung forms a wide band extending across the quadrangle through the foothills of the Allegheny Mountains. In most places it weathers so as to produce high, rounded hills, with here and there a sharp ledge protruding. Good exposures may be found along most of the runs. The dip of this formation is comparatively uniform, in few places less than 14° nor more than 25°. The soil as a rule is too stony or dry for good farming land, and much of the area underlain by this formation is covered with forest, although there are farms on some parts of it.

Fossils and correlation.—The lists of fossils given above include so many species which are typical of the Chemung of New York and other localities that the fauna may be regarded as a typical Chemung fauna. In addition to the species mentioned, *Leptodesma sociale* Hall was found near the base of the formation on Antis Run. The purplish color that characterizes a considerable part of the upper portion persists southwestward into Blair and Huntingdon Counties, where it extends through the upper 1,000 feet of the formation, and northwestward into Warren County and other parts of northwestern

Pennsylvania and western New York, where the upper 400 feet of the Chemung is reddish and is known to the oil-well drillers as the "pink rock."

CATSKILL FORMATION

Character and thickness.—There is some evidence that the Chemung formation of this quadrangle grades upward through green and red shales into the overlying Catskill formation, but there is one marked difference between the two formations in that the Chemung is fossiliferous to its upper limit, whereas the Catskill has so far proved to be nearly nonfossiliferous in the Bellefonte quadrangle except for some plant remains. It is now known that the Catskill is a lithologic facies that in going eastward from central Pennsylvania extends downward through the stratigraphic column, first through the Chemung, then through the Portage, and finally in eastern Schoharie County, N. Y., 1,500 feet below the top of the Hamilton.[49]

There is no good continuous exposure of the whole Catskill formation in the quadrangle, but good partial exposures are abundant, from which it can be seen that it consists chiefly of soft bright to dull red and chocolate-brown shale or mudrock and of reddish sandstone. It contains some thin layers of bright-green and olive-green shale and some of gray sandstone 20 feet or more in maximum thickness. There is a very marked similarity throughout the formation, with its alternation of thick and thin bright-red to dark-red shales and sandstones, with here and there a thin layer of reddish-brown to chocolate-brown or of olive-green to bright malachite-green rocks. Muscovite is plentiful throughout the formation. The sandstones offer very few beds suitable for building stone, although the color of many of them is attractive.

The bright-green portions of the formation occur in thin layers, many of them less than an inch thick, in the red shale and also in irregular blotches in the red sandstone. The cause of the green coloring is probably local deoxidation of the prevailing red ferric oxide to green ferrous oxide. The green beds are distributed throughout the formation, almost from the top to the bottom, and are especially abundant in the lower portion. In the upper part of the formation olive-green, gray-weathering sandy shale is common, and the contact with the Pocono is in many places obscure. There are several thin beds of a peculiar concretionary, calcareous rock at 300 feet below the top and another at 700 feet. Ripple marks and sun cracks also have an extensive vertical distribution, and some of these cracks are wider than those usually found; one seen was 1½

[49] Cooper, G. A., Stratigraphy of the Hamilton group in eastern New York [abstract]: Geol. Soc. America Bull., vol. 44, p. 200, 1933.

inches in width. Cross-bedding is also characteristic of many of the sandstone beds. In the basal shale and sandstone beds dark-gray, drab, brown, and bright-red shale fragments, usually angular, are plentiful.

The thickness of the formation as delimited in this quadrangle differs considerably from place to place, as it measures 1,600 feet above Gum Stump, on the Snowshoe branch of the Pennsylvania Railroad, and 1,200 feet near the west border of the quadrangle. The differences in the determinations of thickness may be due to differences in the location of the boundary between this formation and the Pocono. An attempt has been made to place the contact where the red shale and sandstone beds cease to be prominent, but as the Catskill is not sharply differentiated from the Pocono above, the results reached in different localities may not be consistent. There is the further possibility that part of the formation on the west side of the quadrangle is cut out by an undiscovered fault.

Distribution and surface form.—The Catskill formation crops out over a broad band that extends nearly northeastward across the northwestern part of the quadrangle. The topographic features of the formation are of two types—rolling hills, which are usually cultivated and covered with comparatively fertile farms, and abrupt slopes, where this formation is protected by the overlying more resistant Pocono sandstones. Small fruits seem to thrive particularly well on the clay left from the decomposition of the red sandstone and shale. Exposures of this formation may be found along most of the small streams and many of the roads, especially the roads leading from Gum Stump toward the northeast and northwest and the roads north of Unionville and Julian. The Pocono sandstones protect the Catskill to some extent and usually rise as an escarpment above it. Well-marked terraces are common on the mountain sides, where the more resistant portions of the formation produce steplike forms below the softer shaly beds. The dip in the vicinity of the Snowshoe branch of the Pennsylvania Railroad is from 0° to 15° NW.; north of Unionville it is about 5° to 15° NW.; and in the western part of the quadrangle it is 10° to 22° NW.

Fossils and correlation.—The gray shale and gray sandstone of the Catskill carry a few fossils of Chemung type, which are, however, of little use in correlation. Very rarely a characteristically sculptured scale of *Holoptychus*, a fresh-water fish, is found in the red sandstone. Fronds of the fern *Archaeopteris* occur very rarely. The lithologic characters and stratigraphic position of the formation above the Chemung and below the Pocono serve to correlate it with the Catskill of western New York and of other areas in Pennsylvania with which it is connected by continuous outcrop.

CARBONIFEROUS SYSTEM

The Carboniferous system is represented in this quadrangle by the Pocono and Mauch Chunk formations of the Mississippian series and the Pottsville conglomerate of the Pennsylvanian series. As there is no abrupt lithologic change from the uppermost Devonian to the basal Carboniferous rocks and no detectable structural irregularities under the conditions of exposure, it is generally very difficult to separate the rocks of the two systems.

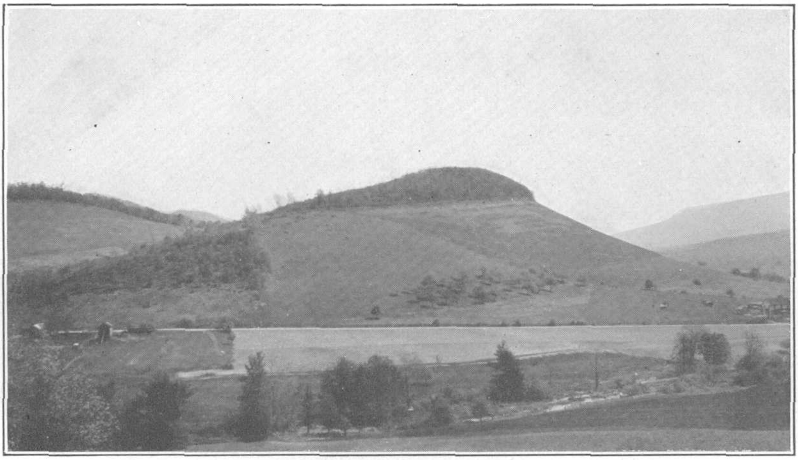
MISSISSIPPIAN SERIES

POCONO FORMATION

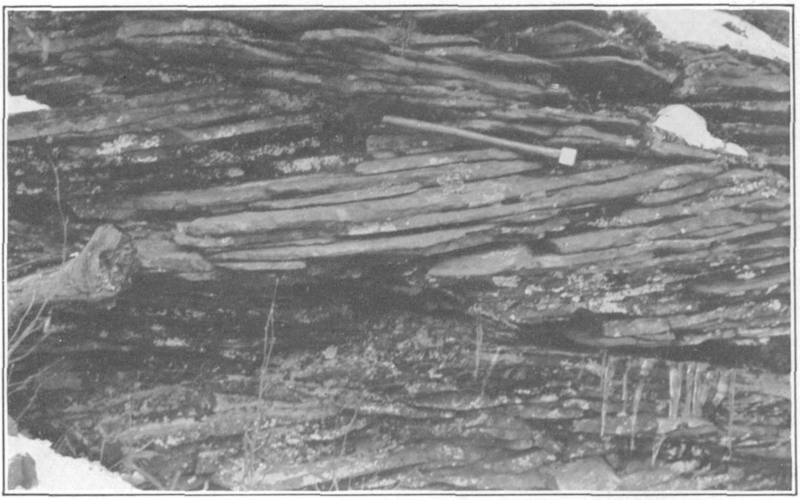
Character and thickness.—The Pocono of the Bellefonte quadrangle is divisible into two members. The lower member is characteristically a thin-bedded gray, brown, red, or yellowish arkosic and shaly sandstone or, as in the fully exposed section on the Pennsylvania Railroad at the famous Horseshoe Curve in Blair County, an alternation of such beds of sandstone with beds of red and green or gray shale. The lower part of this lower member contains more shale and a greater proportion of red material, whereas toward its top there is a greater proportion of coarse-grained sandstone like that of the upper member. In the lower 50 feet are thin lenses of a ferruginous, calcareous conglomeratic rock, with calcareous algae and fragments of fish bones. The best-developed bed of this rock is exposed in a cut on the upper track of the Snowshoe branch of the Pennsylvania Railroad, a little southeast of Clarks station. This lens is just above the bottom of the Pocono. A bed of identical character occurs in the bottom of the Pocono in Riddlesburg Gap, 2 miles west of Riddlesburg in Bedford County.

The upper member of the Pocono, which seems to correspond to the Burgoon sandstone of other areas in Pennsylvania, consists very largely of thick-bedded quartz sandstone strongly resembling the sandstone of the overlying Pottsville formation. Some of it is notably cross-bedded. (See pl. 11, *B*.) The sandstone is gray and generally coarse-grained; many of the grains are angular. The cement is principally soft iron oxide, and the rock disintegrates readily, leaving a barren surface covered deeply with white and brown sand, so that it is poorly adapted for agriculture.

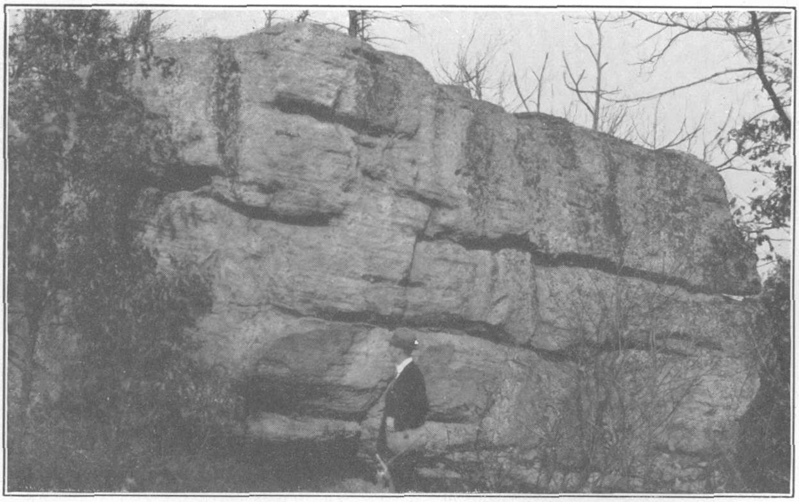
At the base of this member is a considerable thickness of rather coarse conglomerate which may not be persistent. Where best developed there are several beds of conglomerate interbedded with rather coarse sandstone. The conglomerate consists chiefly of well-rounded to angular, almost pure-white quartz pebbles, most of which are small, the largest seen being 1½ inches in diameter. These



A. ROUNDED HILL OF HARRELL SHALE CAPPED BY BRALLIER SHALE.
Looking northwest in Bald Eagle Valley. Photograph by E. S. Moore.

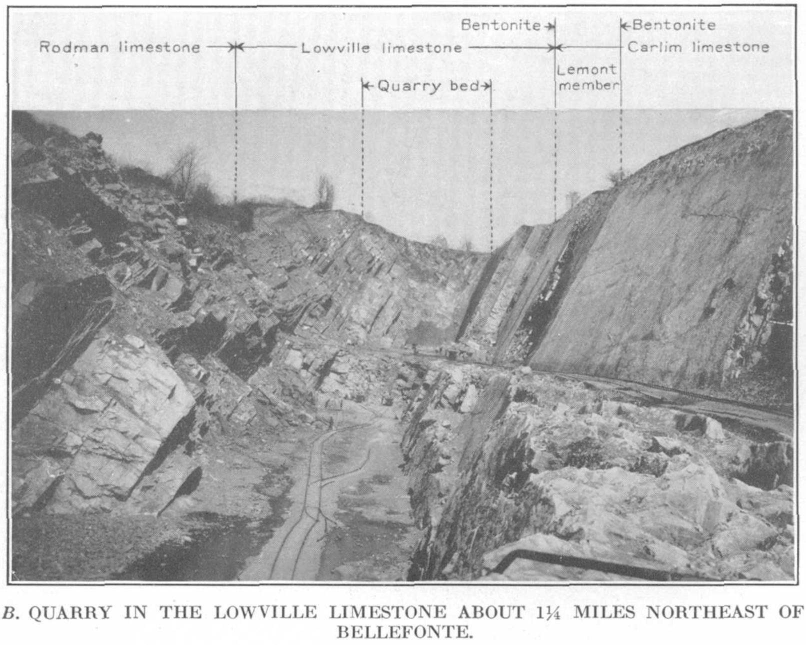


B. CROSS-BEDDING IN BURGOON SANDSTONE.
On the Allegheny escarpment north of Julian. Photograph by E. S. Moore.



A. BLOCK OF SANDSTONE, PARTLY CONGLOMERATIC, FROM THE BURGOON SANDSTONE MEMBER OF THE POCONO.

Summit of Allegheny Front at Bear Rocks, 5 miles northwest of Unionville. Photograph by E. S. Moore.



B. QUARRY IN THE LOWVILLE LIMESTONE ABOUT 1¼ MILES NORTHEAST OF BELLEFONTE.

Just northeast of the Bellefonte fault. Looking northeast. Photograph by E. S. Moore.

pebbles are very unevenly distributed through the beds. There are also numerous fragments of red and green shale, as well as nodules of iron oxide, all of which readily weather out on exposure, leaving holes in the rock.

The thickness of the lower member is placed at 525 to 600 feet, and that of the Burgoon (?) member at 500 feet.

Distribution and surface form.—The Pocono formation occupies the whole northwest corner of the Bellefonte quadrangle. The thick sandstone and conglomerate beds of the Burgoon (?) member generally form a capping for the Allegheny Mountains (the Appalachian Plateau) in this quadrangle, whereas the lower sandstones form the upper part of the Allegheny Front and as a rule produce steep slopes. The gentle dips and resistant character of the Pocono account, to some extent, for the evenness and comparative uniformity of the general level of the plateau surface above the escarpment.

Good exposures of the conglomerate are rather rare. Wherever it comes to the surface on steep slopes it breaks down, generally into boulders of moderate size, but in places it yields large blocks, which occur on the upper part of the Allegheny Front and with many smaller boulders strew the sides and bottoms of all the small ravines in the plateau. (See pl. 12, *A*.) One of these blocks in Rock Run measured 25 by 6 by 2½ feet. The Bear Rocks consist of huge masses of this conglomerate. There are many large boulders on the summit along the highway just north of the quadrangle, 1 mile north of Clarks station, and an exceptionally good display of the conglomerate on the spur contoured at 2,340 feet just north of the Unionville-Philipsburg road on the Allegheny Mountains, 2½ miles west of Bellegrove School. Here 20 feet of conglomerate is exposed and a thickness of 50 feet is indicated.

Fossils and correlation.—A few identifiable species of plants have been collected from the lower half of the Pocono along the Pennsylvania Railroad at the Horseshoe Curve, in the northwest corner of the Hollidaysburg quadrangle. The Pocono of that locality is in the same belt of outcrop as that in the Bellefonte quadrangle, and the same horizons of the Pocono as those in the Bellefonte quadrangle are undoubtedly represented in the collection. The forms as identified by White are listed below.

Taeniocrada sp. (new?).
Archaeopteris, probably n. sp.
Sphenopteris n. sp.
Eskdalia? sp.
Lepidodendron chemungense (Hall) Dawson.
Lepidodendron corrugatum Dawson.
Lepidodendron corrugatum n. var.
Lepidodendron scobiniforme Meek.

Lepidodendron chemungense and the genus *Taeniocrada* are reported elsewhere only from Upper Devonian beds. *Archaeopteris* is usually regarded as an Upper Devonian genus, but *A. obtusa* Lesquereux occurs in the lower Mississippian one-third of a mile north of Bingham, McKean County, Pa. *Lepidodendron corrugatum* is a common form of the basal Mississippian Horton formation in Canada. It has also been identified by Dawson from specimens collected in Mississippian beds in the vicinity of Akron, Ohio. *Lepidodendron scobiniforme* was described by Meek from material collected from lower Mississippian beds in Virginia. The mixture of plants of Upper Devonian and basal Mississippian age is quite in the order of things in a formation just overlying beds of the Devonian system. It is to be noted, however, that *Lepidodendron corrugatum* and *L. scobiniforme* are of lower Mississippian age where elsewhere known and so are fairly good evidence for the same age of the beds containing them in central Pennsylvania. From beds associated with those that carried the plants at Horseshoe Curve were obtained a *Lingula* and a pelecypod (clam), suggesting a *Mytilarca*, neither of which has any correlative value. The bed carrying the fish remains and calcareous algae mentioned on page 74 as occurring near the base of the Pocono near Clarks station also occurs in the Pocono, near the bottom, on the railroad 2 miles north of Riddlesburg, Bedford County. So it is reasonably certain that the boundary as placed here is at the same horizon as that in the Broadtop Mountain region.

By actual tracing of the Pocono westward by means of outcrops and well logs it can be shown that the Burgoon sandstone member is the same as the Big Injun sand of the oil operators, which in turn can be identified beyond reasonable doubt with the Logan formation of Ohio. The part of the Pocono below the Burgoon can be identified in the same way with the Cuyahoga formation of Ohio. It is now known that the Logan and Cuyahoga correspond to the New Providence shale of Kentucky and Indiana and to beds below the top of the lower Burlington of Iowa and Missouri.

HIATUS BETWEEN POCONO FORMATION AND MAUCH CHUNK FORMATION

There are no rocks in western Pennsylvania corresponding to the Keokuk, Warsaw, and St. Louis limestones of the Mississippi and Ohio Valleys. Furthermore, the Loyalhanna (†Siliceous) limestone, of Ste. Genevieve age, which farther southwest in Pennsylvania comes in between the Pocono and Mauch Chunk, is absent in the Bellefonte quadrangle. The Mauch Chunk formation, which immediately overlies the Loyalhanna limestone in the southwestern part of the State, directly succeeds the Pocono of the Bellefonte quadrangle, so that there is here, between the Pocono and the Mauch

Chunk formation, an unconformity which, measured by the absent formations, amounts to a maximum thickness of nearly 2,000 feet of rocks, mainly limestone.

MAUCH CHUNK FORMATION

The Mauch Chunk formation is poorly exposed in the Bellefonte quadrangle and occupies but a small area at the highest point in the quadrangle, which is the hill on the Philipsburg road about 6 miles west-northwest of Unionville. The formation is composed of soft micaceous yellowish and greenish sandstone and sandy shale and a little red shale.

A better outcrop of similar rock is found between the coarse Pottsville conglomerate and the Pocono formation along the Pennsylvania Railroad track where it crosses this formation just north of the quadrangle border. From these two occurrences the thickness of the formation is estimated at 30 feet.

Fossils and correlation.—The Mauch Chunk is not a fossiliferous formation in central and eastern Pennsylvania, the region of its maximum development. Where it appears on the crest of the Chestnut Ridge anticline, in southwestern Pennsylvania and western Maryland, however, it includes a bed of fossiliferous limestone, about 20 feet thick, known as the Greenbrier limestone member. By its fossils the Greenbrier limestone is correlated with the Maxville limestone of Ohio, which is mainly of early Chester age.

HIATUS BETWEEN MAUCH CHUNK FORMATION AND POTTSVILLE CONGLOMERATE

In central and western Pennsylvania and other regions in the western part of the Appalachian Plateaus the Mauch Chunk formation, or, where that is absent, the Pocono formation, is succeeded above by rocks of middle Pennsylvanian age. The lowest division of the Pennsylvanian, the Pottsville formation, has been subdivided by White into lower, middle, and upper Pottsville, the middle and lower subdivisions including all of the Pottsville below the top of the conglomerate overlying the Lykens no. 2 coal bed of the southern anthracite field, in the eastern part of the State. The thickness included in that field is about 1,000 feet, and in the Alabama coal fields the corresponding parts of the Pottsville are 2,500 to 7,500 feet thick. As there are no beds in the Bellefonte quadrangle corresponding to the middle and lower Pottsville, as shown in the accompanying table, there is a great stratigraphic gap or hiatus in this region between the Mauch Chunk and the overlying rocks of the Pennsylvanian series.

PENNSYLVANIAN SERIES

The Pennsylvanian series or coal measures of Pennsylvania is divided into several formations, as shown in the following table. Of these formations only a part of the rocks of upper Pottsville age are present in the Bellefonte quadrangle.

Formations of the Pennsylvanian series in Pennsylvania

<table>
<tr><th colspan="2">Western Pennsylvania</th><th>Bellefonte quadrangle</th><th>Anthracite field</th></tr>
<tr><td colspan="2">Monongahela formation.
Conemaugh formation.
Allegheny formation.</td><td>Absent.</td><td>Coal measures (Buck Mountain coal at base).</td></tr>
<tr><td rowspan="5">Pottsville formation.</td><td>Homewood sandstone member.
Mercer shale member.</td><td>Absent.</td><td rowspan="3">Upper Pottsville (including Lykens no. 1 coal).</td></tr>
<tr><td>Connoquenessing sandstone member.</td><td>Pottsville conglomerate.</td></tr>
<tr><td>Sharon shale member.
Olean or Sharon conglomerate member.</td><td>Absent.</td></tr>
<tr><td>Absent.</td><td>Absent.</td><td>Middle Pottsville (including Lykens nos. 2 and 3 coals).</td></tr>
<tr><td>Absent.</td><td>Absent.</td><td>Lower Pottsville (including Lykens nos. 4, 5, and 6 and Lykens Valley coals).</td></tr>
<tr><td colspan="4">Mauch Chunk shale (Mississippian).</td></tr>
</table>

POTTSVILLE CONGLOMERATE

Character and thickness.—Like the Mauch Chunk, the Pottsville occupies a small area in the Bellefonte quadrangle. The formation consists of sandstone and quartz conglomerate very much like the Pocono but as a rule differing in the larger size of the pebbles. These pebbles are water-worn, and some of them reach a diameter of 2½ inches. The matrix is nearly all a pure quartz sand. Although the Pottsville formation elsewhere carries valuable coal beds, none are known in the small thickness present in this quadrangle.

The formation is well exposed along the Pennsylvania Railroad track just north of the quadrangle boundary, where it is immediately overlain by shale of the Allegheny formation of the Snowshoe coal-mining field. Its thickness here is estimated at 75 feet.

Distribution.—So far as known, all that remains of this formation in the Bellefonte area is a thin coating, mostly of fragments, on the highest hill in the quadrangle, contoured at 2,440 feet above sea level, near the west boundary of the quadrangle and 6 miles south of its northwest corner. Possibly, however, some of the other high knobs in the northwestern part of the quadrangle carry a thin cover of Pottsville.

Fossils and correlation.—In the Ebensburg and Patton quadrangles, as described in the Ebensburg and Barnesboro-Patton folios, the basal Pottsville sandstone is overlain by coal-bearing shales carrying fossil ferns that characterize the Mercer shale member. For this reason the basal sandstone there is regarded as the Connoquenessing sandstone member, which in normal sequence next underlies the Mercer member. As the Pottsville of the Bellefonte quadrangle is probably the same as the basal Pottsville of the quadrangles mentioned, it too is correlated with the Connoquenessing sandstone.

QUATERNARY SYSTEM

The streams in the Bellefonte quadrangle are generally bordered by alluvial material, which consists of the finer silt, sand, gravel, and boulders washed from the higher ground and deposited along the valley flood plains as they have been overflowed by the streams. The largest area of alluvium is the broad strip along Bald Eagle Valley that makes level farm lands. The depth of the alluvium ranges from a few feet to 50 feet or in places possibly as much as 100 feet. The valleys of all the other streams are narrow, and very little fluviatile material is left along their courses. In the valley of Buffalo Run, near Waddle, the debris in the bottom seems to be unusually deep, as a well is said to have been sunk 70 feet without striking solid rock. The talus from the Tuscarora and other formations that crop out on the crest or high on the slope of Bald Eagle Mountain is spread down the northwest side of this mountain to the bed of Bald Eagle Creek.

STRUCTURE

FOLDS AND FAULTS

The Bellefonte quadrangle lies upon the great Nittany arch, one of the major structural features of the earth. This fold starts on the southwest in Bedford County and extends in a curve convex to the northwest to the Susquehanna River near Williamsport, a distance of 150 miles. It diminishes in amplitude northeast of the Nittany Valley region and becomes a relatively minor feature at the Susquehanna. Its greatest width is 35 miles as measured along a line passing northwestward near Hollidaysburg. This line extends from the bottom of the Broadtop Mountain trough in Huntingdon County to the Wilmore syncline a few miles west of the northwest corner of the Hollidaysburg quadrangle. If the strata that have been eroded from the crest of this arch in Nittany Valley and Morrisons Cove were restored, there would rise a mountain 5 miles high. Though essentially one great anticlinal fold, it has superimposed upon it numerous minor folds and is traversed by faults of considerable magnitude. All these features are illustrated by the structure sections in plate 2.

The main arch as well as the minor folds are asymmetric—that is, the northwest limbs have steeper dips than the southeast limbs. Also it is notable that as a general rule the fault planes dip southeast, as actually observed in a few places. These structural features are due to the fact that the folding and faulting were produced by forces acting in a nearly horizontal direction from the southeast.

Along the Allegheny Front and northwest of it the strata dip constantly at a low angle, perhaps 5°, to the northwest. Southeastward from the front toward the crest of the Nittany arch, the dip constantly steepens and becomes vertical along Bald Eagle Mountain. At the northwest foot of Bald Eagle Mountain there is a persistent small fold, as shown at Milesburg (section A–A′, pl. 2). Locally this fold is replaced by sharp upward flexures, as shown in section E–E′. This fold is persistent as far south as Altoona and shows as a sharp anticline at the south end of the cemetery hill at Tyrone. It is the cause of the repetition of the outcrop of the Helderberg limestone at Milesburg and of the widening of the outcrop of the Lower Devonian farther southwest.

Southeast of Bald Eagle Mountain a minor fold causes the repetition of the outcrop of the Axemann limestone south of Buffalo Run post office. The Axemann is exposed on the opposing limbs where this fold is crossed by the road a mile south of the post office. This anticline and the complementary small syncline probably die out in the southeast corner of the Philipsburg quadrangle, next west of the Bellefonte. About 2 miles southeast of Bald Eagle Mountain is the outcrop of the Birmingham fault, which extends from Canoe Valley, 5 miles south of Tyrone, perhaps to Bellefonte, where its presence may be indicated by a crushed zone in the Nittany dolomite. Its stratigraphic displacement at Birmingham, where it is well exposed in a railroad cut about a quarter of a mile southeast of the railroad station, is about 5,000 feet.

About 1½ miles northeast of Bellefonte is a cross fault of considerable upward displacement on the south which seems to die out westward in the Milesburg gap. In this part of its course it seems to be of the nature of a tear fault or blatt, with a lateral rather than a vertical movement predominating. It has not been traced east of the quadrangle but probably swings northeastward and follows the northwest base of Sand Ridge in the Centre Hall quadrangle. Sand Ridge is probably made by the Gatesburg formation raised up by a fault (Bellefonte?) that crops out along its northwest base. The disappearance of this fault in the vicinity of the Milesburg gap is probably connected with several small faults reported in the Juniata and Oswego formations in that gap. Between the fault and Bald Eagle Mountain the strata are nearly vertical.

Parallel with the Birmingham fault and half a mile southeast of it is the axis of the Buffalo Run anticline, which appears to be the summit of the Nittany arch in this quadrangle, as here the oldest formation, the Warrior limestone, comes to the surface. The asymmetric structure is shown by the dip of 80° northwest of the axis and 30° to 40° southeast of it (section E–E′). Farther southeast on the summit of the Nittany arch are the Marengo syncline, Gatesburg anticline, Hostler syncline, and Pennsylvania Furnace anticline. All these folds converge southwestward and disappear near Grazier Mill, in the Tyrone quadrangle. The main axis is the Gatesburg anticline, which extends clear across the Bellefonte quadrangle. This anticline pitches northeastward apparently to a cross syncline 2 or 3 miles east of Bellefonte, whence it rises farther northeast and causes the Gatesburg to crop out in Sand Ridge, in the Centre Hall quadrangle, beginning 5 miles northeast of Bellefonte and extending along the nearly flat crest of the Nittany arch. The dip is low, 5° to 15° on each side of the axis. The Marengo syncline for most of its distance in this area is very shallow, except in the southwest corner of the quadrangle, where exposures show rather high dips near the southwestward-pitching axis. The Hostler syncline and Pennsylvania Furnace anticline are of small extent in this area but increase in magnitude southwestward. Between the two is a small fault that apparently reaches its maximum displacement near the south boundary of the quadrangle and dies out both to the northeast and southwest.

Except for the minor folds southeast of the Gatesburg anticline in the southwest corner of the quadrangle, the strata dip southeast to the Nittany Valley syncline. The dip is 5°–10° SE. near the Gatesburg axis but increases to 25° along the northwest flank of Nittany Mountain. The southeast dip is interrupted locally by a narrow syncline and a complementary narrow anticline three-fourths of a mile southeast of Pleasant Gap station (section A–A′).

The Nittany Mountain syncline pitches to the northeast and conversely rises to the southwest and becomes indistinguishable near the south boundary of the quadrangle.

From Nittany Mountain the strata rise very steeply to the axis of the Penn Valley anticline, which pitches to the southwest and dies out in a broad area of strata of low southeastward dip in the vicinity of Bloomsdorf. Its northeastward extent toward Centre Hall is not known to the writers.

A small syncline and anticline lie in the southeast corner of the quadrangle. The anticline has its main extent northeast of this quadrangle, and both anticline and syncline die out within a short distance on the northwest slope of Tussey Mountain.

In the extreme southeast corner of the quadrangle there is a flattening of the rocks as they approach the northeast end of a syncline 2½ miles east of the quadrangle, and the decrease in dip spreads the outcrops of the Oswego sandstone and Juniata formation to several times their width on Tussey Mountain 5 miles south of the quadrangle. As a result the Oswego here makes the main crest of Tussey Mountain, as shown on the map. The Tuscarora quartzite, which generally makes the crest of the mountain, just enters the southeast corner of the quadrangle as part of a ridge on the north limb of the syncline which, south of the quadrangle, opens out southwestward between two ridges of the Tuscarora. The north ridge, running nearly west just south of the Bellefonte quadrangle, joins the above-mentioned part of Tussey Mountain capped by Oswego sandstone half a mile south of the quadrangle and becomes the main crest of the mountain.

MINOR FEATURES

Edgewise conglomerate.—A minor structural feature that is common in some layers of limestone, especially in the Stonehenge limestone, is known as "edgewise conglomerate." This rock consists of thin, flattish pebbles of limestone, most of them with rounded edges, irregularly embedded in a matrix of limestone that commonly contains a little sand or clay. The pebbles are supposed to owe their origin to the drying and cracking of calcareous muds on tidal flats and the washing of the fragments together in a heterogeneous arrangement. The fragments are locally replaced by silica, as shown by the fact that some of them consist of a chert exterior surrounding a core of limestone.

In the Bellefonte quadrangle rock of this type occurs as thin layers in the Warrior limestone, as many thick and thin beds in the lower 150 feet of the Stonehenge limestone, and as thinner bands higher in the Beekmantown and younger limestones. It is much more common in limestone than in dolomite and as a rule occurs in the thinner layers. Layers of limestone conglomerate and layers of limestone containing almost complete gastropod shells occur interbedded with each other, showing alternating brief periods of agitated and quiet water.

Dolomite gashes.—The weathered surfaces of many layers of the dolomites of this area show many crisscross cracks strongly resembling the small gashes that may be seen on the surface of slightly frozen or drying mud. Such gashes are common in the dolomites of the Appalachian Valley. They are restricted to dolomite and afford a criterion for distinguishing it from limestone. Their origin is unknown.

GEOLOGIC HISTORY

PROTEROZOIC ERA

In the Proterozoic era were deposited stratified rocks older than the earliest rocks that contain an abundance of recognizable fossils. At the end of the era these rocks formed a land mass in the central United States and another one extending along the Atlantic coast from Newfoundland to Florida. Between the two land masses a comparatively narrow trough known as the "Appalachian Strait" extended from the Gulf of St. Lawrence through central Pennsylvania to the Gulf of Mexico. Proterozoic rocks formed the bottom of this strait and made the foundation upon which the overlying Paleozoic rocks in this region were deposited.

PALEOZOIC ERA

The Paleozoic era is the era of ancient life. All the great classes of invertebrate animals were already differentiated at its beginning, and the lower classes of vertebrates—the fishes and amphibians—appeared before its end.

CAMBRIAN PERIOD

The oldest Cambrian rocks of Pennsylvania do not crop out in the Bellefonte quadrangle but are believed to underlie the area at considerable depth.

At the beginning of the Cambrian period coarse sediment was discharged from the bordering lands into the Appalachian Strait and formed strata of sandstone, conglomerate, and shale, in places supposed to be more than 10,000 feet thick. These rocks, which now crop out in South Mountain, Pa., and along the Blue Ridge of Virginia, are believed to extend westward, in places at least, and to underlie the Bellefonte quadrangle at considerable depth.

Deposition of limestone followed, and this after change to dolomite became the omstown dolomite of Pennsylvania and the equivalent Shady dolomite of the southern Appalachians. These are the oldest calcareous rocks in the Appalachian Valley. Their deposition indicates a change of geographic or climatic conditions, possibly a wearing down or sinking of the land, from which the slow streams would carry little or no sediment to the strait, or possibly a desert condition, with no drainage. Again the conditions changed, and red and green mud, sand, and fine gravel were deposited, making the rocks of the Waynesboro formation. The red mud could have originated through the deep decay of the rocks of the land during Tomstown time, when there was little erosion, red sediment being considered by many a result of desert conditions. The second change to deposition of limestone in the Pleasant Hill and Warrior epochs may plausibly be associated with a period of widespread submergence of the area that now forms the interior of the United States, during which shore lines were far removed from this region. The Pleasant Hill sea, in which the Pleasant Hill limestone of Blair County was deposited, was invaded by trilobites and brachiopods near the end of the epoch. (See p. 15.) Precipitation of calcium carbonate from the water, possibly through the agency of bacteria or algae, continued through the Warrior epoch. Most of the Warrior deposit, however, is now a dolomite, or magnesian limestone, probably the product of a concentration of magnesium salts in the sea water caused by rapid evaporation.

Some of the geographic conditions at this time are indicated by the sandy layers of the Warrior. The Bellefonte region must have been near the shore of the Warrior sea, where it was entered by streams carrying the sand and coarser quartz grains.

Trilobites and oboloid brachiopods lived in the sea from time to time, as shown by their fossil remains found at several horizons. A species of the marine alga *Cryptozoon*, a low plant form, was one of the principal inhabitants of the Warrior sea.

As the Warrior limestone apparently represents only about the first half of Upper Cambrian time, Mr. Butts believes that there is an unrecorded interval here corresponding to the second half of Upper Cambrian time in which a considerable thickness of Upper Cambrian sediments was deposited in Wisconsin and a still greater thickness in the Rocky Mountain region. This unrecorded interval was followed by submergence and the deposition of the Conococheague limestone.

After Warrior time the area that is now central Pennsylvania lay in the midst of a wide sea bordered by low lands. In Gatesburg time at least some parts of the bordering land yielded great quantities of quartz sand. A somewhat arid climate may have prevailed, resulting in concentrated saline water that favored the deposition of a great thickness of coarse dolomite. The sand may have been carried to the sea by intermittent floods, as in modern desert regions, to form the recurrent beds of sandstone, or it may have been blown into the sea by winds, as it is now blown about in desert regions or along seacoasts, forming the well-known sand dunes, and afterward widely distributed by oceanic currents.

At the beginning of the succeeding Mines epoch the sea was invaded in places by swarms of gastropods, the fossils of which are in such places plentiful in a 2-foot layer at the base of the formation. The general geographic and climatic conditions of Gatesburg time continued, possibly with a still wider sea and less drainage, with resulting cessation of transportation of sand but possibly with increase of disseminated silica to form the chert of the Mines dolomite.

It is believed that at the end of the Mines epoch the sea bottom was uplifted into dry land and so remained in this area, resulting in an unrecorded interval here, while in Huntingdon and Blair Counties the Larke dolomite, about 250 feet thick, was deposited. Then the land of the Bellefonte area sank, the sea again spread over it, and the deposition of the earliest Ordovician of the region, the Stonehenge limestone, began. However, lagoons probably existed in which a few Chepultepec animals lived.

ORDOVICIAN PERIOD

During most of the Ordovician period limestone and dolomite were deposited in this region. In the later part of the period clastic sediment, which now forms the Reedsville shale, was brought in.

In the early part of the period, the Stonehenge epoch, pure calcium carbonate to form limestone was deposited. At times trilobites, gastropods, and brachiopods flourished. In the succeeding Nittany epoch calcareous sediment, later becoming dolomite, was deposited. In the succeeding Axemann epoch the deposition of calcium carbonate to make limestone predominated, and conditions were favorable for abundant life. In the following Bellefonte epoch calcareous sediment that merges into dolomite was again deposited. Throughout these four epochs gastropods were predominant forms of animal life, with fewer cephalopods, brachiopods, and trilobites; plant life in a very low form was represented by Cryptozoa, which are supposed to be lime-secreting algae. The Stonehenge, Nittany, Axemann, and Bellefonte formations constitute the Beekmantown group of this area.

Beekmantown time was followed by an unrecorded interval, corresponding to the early part of the Chazy epoch, the rocks of which, several hundred feet thick, are absent in this region. The absent formations are the St. Peter sandstone and associated formations of the Mississippi Valley and part at least of the Murfreesboro limestone, 500 feet thick, of Tennessee. The whole Appalachian Valley probably was dry land of very low relief during most of the unrecorded time. After this unrecorded interval the sea, gradually transgressing from the southwest, again submerged central Pennsylvania in lower Stones River time or at the beginning of middle Stones River time, and in this sea the Carlim limestone was deposited. Transgression of the sea from the southwest is inferred from the fact that the Murfreesboro limestone is present in southwestern Virginia and that it was laid down in the transgressing water before the submergence reached central Pennsylvania.

The argillaceous Lemont limestone, the top member of the Carlim, grows thicker toward the northeast, and possibly its materials came from that quarter. Shallow water is indicated by ripple marks and mud cracks on some of the limestone layers. Bryozoa, brachiopods, pelecypods, gastropods, ostracodes, and trilobites were the principal inhabitants of the Carlim sea and were most abundant in Lemont time.

For a very long period after Carlim time this region was dry land, whereas the sea covered other parts of the Appalachian Valley, as in eastern Tennessee, where 6,000 to 8,000 feet of strata (Blount group of Ulrich), including the Holston marble, Athens shale, Tellico sandstone, and Sevier shale, were deposited between Carlim and Black River time. These formations are not represented in this part of Pennsylvania.

During most of the Black River epoch much the same conditions prevailed as in the Carlim epoch. In Lowville time the transgression of the Ordovician sea reached its culmination, and the region of the central United States at least was very largely submerged, for in the eastern United States rocks of Lowville age are probably the most widespread of all in the Ordovician system. Life was fairly abundant, especially in Rodman time, and bryozoans, brachiopods, gastropods, and corals were the most common forms. If the Rodman is correctly correlated with the lower *Echinosphaerites* bed of the Chambersburg limestone of the Mercersburg-Chambersburg region, there is a hiatus between the Rodman and Trenton limestones due to the absence of 500 to 600 feet of Chambersburg limestone above the *Echinosphaerites* bed.

Although the deposition of limestone persisted in this region during Trenton time, terrigenous rather than calcareous sediment was being deposited in eastern Pennsylvania, where the lower part of the Martinsburg shale is of Trenton age. Somé of the carbonaceous matter to which the dark color of much of the Martinsburg shale is due and perhaps a little of the finest clay sediment were conveyed to this region, giving the Trenton limestone its shale partings, impurities, and dark color. The same general forms of life inhabited the Trenton sea as flourished in the seas of the preceding epoch, although of different species.

The deposition of the succeeding Reedsville shale marks the beginning of a great change in geographic conditions in the Appalachian Gulf. Uplift of the sea floor, warping, shallowing of the water, and finally a dominance of clastic sediments more marked than had taken place in the region since early Cambrian time are the distinguishing features of the Martinsburg, Reedsville, and succeeding epochs up to the Tonoloway. Not only in central Pennsylvania, but also over a very large part of the region of the eastern United States, the deposition of fine muds was the rule during the Reedsville epoch. The strait had probably become a broad, comparatively shallow gulf, agitated by great waves and swept by tidal and possibly strong oceanic currents.

Conditions were generally favorable to life in this epoch, and at different times the sea bottom must have been covered with shell-bearing animals, for many thin layers of impure limestone composed of these shells are intercalated in the shale.

In the epoch succeeding the Reedsville there were probably lands of moderate relief on the northwest in Canada and on the southeast in the Blue Ridge province, but for a time at least they underwent relative elevation; the shores moved seaward and exposed to subaerial erosion the old submerged coastal shelf, where lay a large body of sandy residue left after the finer material of the Martinsburg shale was washed out and laid down farther seaward. This sandy shelf now became a coastal plain, and the higher land farther from the shore supplied the sandy material of the later Oswego sandstone and Juniata formation of the Ordovician.

Thus the deposits of the succeeding Oswego epoch were predominantly fine quartz sand. The absence of the Oswego southeast of this region, nearer the Blue Ridge, and its presence in central New York indicate an old land northwest of the Appalachian Strait as the source of the sandy sediment.

During the succeeding Juniata epoch the deposition of sandy and muddy sediments continued. Considerable variation in the kinds of sediment discharged into the water or in the transporting power of the currents by which the sediment was distributed is attested by the alternating beds of shale and sandstone. It is supposed that the red sediments predominating in the Juniata were derived from a large area of dry land lying to the north of the Appalachian region, for the Juniata, like the Oswego, is absent from the southeast side of the Appalachian Valley next to the Blue Ridge. On the land had accumulated a deep red residual soil which was transported to the southern sea of the time, occupying a large area in Ohio, Indiana, Kentucky, and Canada, and was deposited on a large tidal flat or as a great delta similar to that now forming along the lower course of the Hwang Ho in China.

SILURIAN PERIOD

The Tuscarora epoch was one of widespread deposition of pure quartz sand in the Appalachian province. This formation implies much erosion of tributary land and much sorting of material, which left a mantle of comparatively coarse sand on the low land of a wide coastal plain.

The absence of fossils in the Oswego, Juniata, and Tuscarora formations is regarded as very strong evidence that they were all terrestrial, perhaps shore or tidal-flat deposits, exposed to the air all or part of the time, so that marine animals could not live in the area. Also they were laid down before air-breathing animals had appeared upon the earth. Similar deposits of later times contain the tracks and fossil remains of air-breathing animals.

During the Clinton epoch the region was again submerged in the sea, which at times swarmed with ostracodes and other invertebrates. The feature, however, that peculiarly distinguishes the Clinton formation is the occurrence of beds of fossil and oolitic iron ore. These beds are present along the Appalachian Valley from New York to Alabama and point to a remarkable uniformity of conditions. That the iron was deposited contemporaneously in the beds in which it occurs is the most generally accepted hypothesis. Extensive more or less sheltered lagoons in which animals flourished may have existed. The shells and other skeletal parts of the animals, usually in a comminuted state, such as the coquina found in Florida at the present time, accumulated in these lagoons, and as calcium carbonate precipitates iron from solution, the iron possibly brought into the lagoons in solution as iron carbonate or iron sulphate was precipitated and mixed with the animal debris, ultimately forming the ore beds.

Between the Clinton and McKenzie epochs was an unrecorded interval during which the Lockport dolomite, absent in Pennsylvania, was deposited in New York and Canada.

Pure limestone marks the beginning of the McKenzie epoch. Later argillaceous sediments predominated. Animal life flourished, and ostracodes and brachiopods were very abundant.

In the succeeding Bloomsburg and Wills Creek epochs fine sediment, at intervals calcareous, seems to have been laid down everywhere, an exception in this region being the few beds of red sandstone and shale in the Bloomsburg. In marked contrast with the preceding McKenzie sea the Wills Creek sea in this region was very nearly destitute of inhabitants. The salt and gypsum deposits of the equivalent Camillus (Salina) formation of New York indicate a more or less isolated body of water and an arid climate with excess of evaporation. Such conditions, though perhaps less extreme, may have existed in central Pennsylvania during the epoch.

During the Tonoloway epoch the deposition of nearly pure calcareous sediment, for the first time since the Trenton epoch, was resumed in this region. Land was probably far distant.

DEVONIAN PERIOD

By the beginning of the Devonian period the Appalachian Gulf had contracted to a rather small basin occupied by the sea of earlier Helderberg time, supposedly connected with Atlantic waters, but there is no obvious evidence of a significant stratigraphic break between the Silurian and Devonian in this region. This sea expanded to the southwest and possibly to the northeast, and after Onondaga time it received from the highlands on the east and northeast a vast amount of sediment which spread out delta-like from the head of the sea or gulf in the region of the Catskill Mountains in southeastern New York and extended southwestward into southwestern Virginia and over most of West Virginia and eastern Ohio. The area was continuously submerged and received deposits of clay and sand during the whole of Devonian time after the Helderberg epoch.

The narrow Helderberg sea of the central Appalachian region extended from New York through central Pennsylvania to southwestern Virginia and was probably surrounded by very low lands on which slight erosion was going on. Deposition of limestone prevailed, and conditions were favorable to life. Many of the inhabitants of the Helderberg sea were survivors from the Silurian, and some new types were introduced.

As the Becraft limestone, the top member of the Helderberg, has not been recognized in central Pennsylvania, there is believed to be a slight hiatus between the Helderberg and the Shriver, next in succession.

The Oriskany epoch marked the beginning of a revival of the transporting power of streams. Fine sand was mixed with calcareous sediment to form the thinner siliceous limestone of the Shriver formation. Later, with increased power of transportation, coarser sand and small quartz pebbles were delivered by the streams to the highly calcareous sea to form the calcareous Ridgeley sandstone. The Appalachian Gulf in the Oriskany epoch extended from Canada to southwestern Virginia, and perhaps the Appalachian Valley area was occupied by shallow lagoons as far south as Alabama and Georgia, where isolated Oriskany deposits occur. During Shriver time conditions were less favorable to life than in the Helderberg, but in Ridgeley time they again became favorable, and the sea bottom was thickly populated by shell-bearing invertebrates, especially brachiopods and gastropods.

Onondaga time does not appear to have been recorded in the Bellefonte region, but in other parts of central Pennsylvania the deposition of fine shaly and limy sediments prevailed. On the north and west, in New York and Ohio, only limestone was laid down. The shale and limestone of central Pennsylvania were near-shore deposits, and the limestone on the north and northwest was deposited farther from shore, in clear water. Animal life was not abundant, but in the Onondaga sea of other regions it was profuse.

The rocks of the Marcellus, Hamilton, Portage, and Chemung formations were laid down in a more or less landlocked bay or gulf, the head of which was in southeastern New York. The clay, silt, and sand that built up these formations were apparently derived from land on the northeast and southeast, whose western shore probably extended from New York southward some distance west of the present line of the Blue Ridge. The character of these formations indicates accumulation in shallow water and, as they are 7,000 or 8,000 feet thick, a long period of slow and constant subsidence of the floor of the Appalachian Gulf.

The Marcellus sea was sparsely populated except by small pteropods (*Styliolina*), which were abundant. So was the Hamilton sea in this region except near the end of its existence, when bryozoans and brachiopods flourished and many other forms were common. The inhabitants of the Portage sea were peculiar diminutive pelecypods and gastropods, which seem to have lived in small numbers throughout the epoch, and some larger and still less abundant cephalopods. The Chemung fauna was more abundant and the forms of life were larger, brachiopods and pelecypods predominating in number of species and individuals. Some fish, earliest of the vertebrates, swam in the sea. The distribution of certain fossil forms proves that from late Hamilton time through Portage time the sea covering the central Pennsylvania region was in some way connected with that of western Europe (Rheinland) by way of the Mackenzie River, central Asia, and northern Europe or eastward by way of the Atlantic Ocean.

Before the beginning of Chemung deposition—in fact, in Hamilton time—the Catskill facies of sedimentation began in eastern New York with red rocks and continued with the deposition of the Oneonta sandstone. From this time onward the deposition of red rocks continued, being contemporaneous at first with the marine Portage, later with the Chemung, and at the end probably with early Mississippian deposits. Thus it happens that the Catskill rocks diminish in thickness from the bottom upward as they extend westward, until they are represented in western Pennsylvania and western New York by only a few hundred feet of rocks, characterized by beds of red shale.

As a whole, however, the Catskill is best explained as a dry-delta deposit extending from the Catskill Mountains to Maryland, Virginia, and West Virginia; the upper third or so is represented in western New York and northwestern Pennsylvania by prevailingly marine fossiliferous sediment in which are local red layers. In the Bellefonte quadrangle the delta type of Catskill predominates, but at times the western margin of the delta was submerged and tongues of marine fossiliferous sediment were laid down.

It is thought that the red sediment of the Catskill was derived from the highly oxidized residuum of the deeply decayed crystalline rocks of a very old eastern land surface, such as exists today in parts of the Southern States. This land may have been in the Adirondack or New England region. The gray shale and sandstone strata that occur at several horizons in the Catskill and bear a marine fauna as described above may have had a northwestern source. They may, however, have been derived from the same source as the red sediment and have been bleached by the deoxidizing action of marine waters charged with decaying organic matter.

CARBONIFEROUS PERIOD

In the Bellefonte region sedimentation apparently went on continuously from the Devonian period into the Mississippian epoch of the Carboniferous, although it is questionable whether the Kinderhook of the Mississippi Valley is represented in Pennsylvania. The distinguishing feature of the Carboniferous period was abundant vegetal growth, which supplied the material for coal. It was a time of warm climate and extensive marshes near sea level, in which plants of different kinds grew luxuriantly and on falling were covered by water and so preserved from decay in the same manner as vegetal debris is preserved in the peat bogs of the present day. In this region the same oscillations between marine and nonmarine conditions as in Catskill time persisted, at least in the first half of Pocono time. Nonmarine conditions were fully established in the later part of the epoch, when the Burgoon (?) sandstone was laid down.

In the Bellefonte quadrangle no rocks of Keokuk, Warsaw, St. Louis, or Ste. Genevieve age are present, so that there is an unrecorded interval of great length between the Pocono and Mauch Chunk.

The deposition of the prevailing gray Pocono was succeeded by a third extensive deposition of red beds, composing the Mauch Chunk formation. The conditions in Pennsylvania during Mauch Chunk time were unfavorable for invertebrate and plant life, for the formation contains no coal beds and shows little evidence of the presence of either plants or animals. At the same time, however, in western Pennsylvania and eastern Ohio marine limestones and shales were being deposited upon a sea bottom thickly inhabited by marine invertebrates, whose fossil remains now crowd the Greenbrier limestone member of the Mauch Chunk of Pennsylvania and the contemporaneous Maxville limestone of Ohio.

After the deposition of the Mauch Chunk an unrecorded interval ensued in this region that was long enough for the deposition of 10,000 feet of rock with many coal beds in the Pottsville troughs of Alabama. If these beds were present in this part of Pennsylvania they would lie between the top of the Mauch Chunk and the bottom of the Pottsville beds as described below.

At the beginning of Pottsville deposition there was a sinking trough in eastern Pennsylvania extending southward, bordered around the north end and on the southeast by land, probably high, and on the northwest by low land. From these lands rapid streams brought in immense quantities of coarse material. This deposition of coarse material went on until 1,000 feet of strata containing coal beds was laid down in the southern anthracite field of Pennsylvania and 10,000 feet in Alabama. While these masses of Pottsville sediments were accumulating the land from central Pennsylvania westward had been worn down nearly to sea level, and then, near the end of Pottsville time, it was submerged and sedimentation upon it was resumed. This sedimentation produced first the Connoquenessing sandstone—the lowest member of the Pottsville of the Bellefonte quadrangle.

Deposition continued from the Pottsville into the Allegheny epoch, which was marked by rapidly alternating conditions, and as a result shale, sandstone, limestone, and coal beds succeeded one another at short intervals. Practically all the coal in western Pennsylvania occurs in the Allegheny or in higher formations that do not now exist in the Bellefonte quadrangle. Deposition continued in the region at least through Conemaugh and Monongahela time, as indicated by the presence of rocks of those epochs in Broadtop Mountain. No history of the quadrangle during Permian time, the final epoch of the Paleozoic era, has been preserved, but a considerable thickness of Permian rocks (Dunkard group) was deposited in the extreme southwest corner of the State, and probably Permian rocks were deposited in this region also.

MESOZOIC AND CENOZOIC ERAS

The Paleozoic era had been one of sedimentation in the region now occupied by the Appalachian Valley and Appalachian Plateaus, during which a great series of rock formations was built up. The

Mesozoic and Cenozoic, on the contrary, were eras of deformation and erosion in the region. Very few and fragmentary records of the events of these eras have been preserved in the Appalachian province, although vast changes must have occurred. To a certain extent the history of the region can be inferred from records that persist in other parts of the country.

APPALACHIAN UPLIFT

The Dunkard epoch brought Paleozoic sedimentation in the north end of the Appalachian trough to a close, and a long series of events of a totally different kind began. So far as known, from the end of Carboniferous deposition until the present time dry land has existed in the north end of the Appalachian Valley province, except in the areas covered by Triassic lakes that existed along the Piedmont Plateau from Connecticut to North Carolina. Uplift of the sea bottom was accompanied by strong deformation, by which the originally horizontal sedimentary strata of the Appalachian Valley province were folded into high anticlines and deep synclines, and west of the Allegheny Front into the low anticlines and shallow synclines of the bituminous-coal fields. This folding must have taken place in post-Carboniferous or early Mesozoic time, because the youngest Carboniferous strata (Dunkard group) are involved in it. This profound change in the history of the region is known as the "Appalachian revolution."

CYCLES OF EROSION

The wearing away of land by the processes of erosion is continuous, and if a region should cease to rise or the upward movement become very slow, it would in time be worn down to a plain near to sea level. A surface thus reduced is called a "peneplain." Should a second uplift occur, erosion would be renewed and as before would proceed faster on soft rocks than on harder rocks, which would be left standing as ridges between valleys. The tops of these ridges would for a long time approximately coincide with the surface, now uplifted, of the old peneplain. Such cycles of erosion may be several times repeated and leave remnants of the successive peneplaned surfaces at accordant levels as a series of hill or ridge tops, as benches along the valley walls, or as spurs extending out from them. With these broad principles of erosion in cycles as a clue the post-Paleozoic history of this region can be read from the land forms now existing.

Kittatinny peneplain.—During Triassic and Jurassic time the surface of the uplifted and folded Appalachian Valley province was probably eroded more than once to a peneplain. The first of these plains is called the "Kittatinny peneplain", because what are believed to be remnants of it are well preserved in the flat tops and even crest of Kittatinny Mountain in eastern Pennsylvania. The crests of Dunning and Tussey Mountains in Blair County and the crest of the Allegheny Front also approximately represent the uplifted surface of this peneplain. The Kittatinny peneplain may have been formed during the Jurassic period.

Schooley peneplain.—After the uplift of the Kittatinny peneplain erosion produced a second peneplain, parts of which may be the summits at 1,500 to 1,800 feet above sea level on the eastern foothills of the Allegheny Front and possibly the conspicuous bench about 1,800 feet above sea level on the outcrop of the Oswego sandstone along the east side of Tussey Mountain and the west side of Lock and Dunning Mountains. (See p. 46.) This peneplain is correlated by some with the Schooley peneplain, developed on the Schooley Mountains of northern New Jersey.

It is believed that the Schooley peneplain was completed before the beginning of Upper Cretaceous time, for in New Jersey a remnant of what is supposed to be that peneplain extends seaward beneath deposits of Upper Cretaceous age.

Harrisburg peneplain.—After the formation of the Schooley peneplain the region was again uplifted, erosion was renewed, and the broad, rolling area of Morrison Cove, in Bedford and Blair Counties, now 1,200 to 1,400 feet above sea level, was developed. This area possibly represents the Harrisburg peneplain, well developed near Harrisburg, where its altitude is about 500 feet.

Post-Harrisburg erosion.—The Harrisburg peneplain is supposed to have been uplifted unequally, and modern stream valleys have been eroded below its surface in the later part of Tertiary time and to their present depths in Quaternary time.

Development of drainage features.—When something is known of the history of the region since the Appalachian revolution, as outlined above, it is easy to understand the origin of such gaps through the ridges as McBride Gap and the gap of Spring Creek at Milesburg and many other gaps in adjoining regions. The streams that occupy these gaps took their courses on the nearly level surface of the Kittatinny peneplain, which was topographically above the tops of the ridges of the present day. During subsequent uplifts they maintained their courses as the country rose and eroded their beds to lower levels, while the side streams wore down their valleys on the more easily erodible rocks between the resistant rocks of the ridges. Thus the streams have sawed, so to speak, the gorges through the ridges.

GLACIAL EPOCH

In the Pleistocene epoch of the Quaternary period the northern and central parts of the United States were covered several times by great ice sheets from the Canadian highlands, but these did not reach the Bellefonte region, the southern margin of the ice advance in Pennsylvania being about 70 miles north of Bellefonte.

RECENT EPOCH

In the Recent epoch of the Quaternary period the final sculpturing of the region to its present topographic aspect has been effected, and the Recent deposits of alluvium have been laid down along the lowlands bordering the streams.

PROGRESS OF LIFE

It is probable that the terrestrial plants and animals of Mesozoic and Cenozoic time, whose existence is recorded by their remains in the rocks of those eras along the Atlantic and Gulf coasts and notably in the Rocky Mountains and elsewhere in the far West, flourished in this region also. The cycads and ferns of the Triassic and Jurassic periods doubtless clothed the surface of the land and supplied nutriment to the great reptiles (dinosaurs) and the small mammals that are known, from tracks and skeletal remains found in Connecticut and North Carolina, to have been living as early as Triassic time, and probably the kinds of fish characteristic of the times swam in the rivers and creeks. But no vestige of this life remains in the Bellefonte area, because all deposits in which any of the plants or animals could have been buried and preserved were later swept away in the general erosion of the region.

In the Cretaceous period great forests of deciduous trees must have grown in which must have roamed other forms of gigantic dinosaurs than those of Triassic or Jurassic time. In this period such common kinds of trees as the oak, willow, sassafras, and tulip tree first appeared upon the earth. All traces of the Cretaceous species of these, too, have been obliterated in this region, although their remains, especially leaves, are abundant in the Cretaceous deposits in New Jersey, Maryland, and Virginia, having been borne into the bordering Cretaceous seas and coastal swamps by streams and winds. In Tertiary time many strange forms of mammals, known from their remains in the Rocky Mountains, probably inhabited this region also, and in Pleistocene time extinct animals whose remains are now found in swamps, bogs, and caves of Pennsylvania and Maryland were the common denizens of the land. In a cave at Smith's quarry, half a mile west of Frankstown, Pa., were found remains of a tapir, a *Megalonyx*, two species of peccary, a bison, a mastodon, and a carnivore resembling the jaguar.[50] In a cave near Cumberland, Md., there have been found, among many species, the horse and a supposed eland,[51] the latter now known only in Africa.

ECONOMIC GEOLOGY [52]

The materials of economic importance in the Bellefonte quadrangle are iron ore, limestone, quartz sand, clay, sandstone, soils, and water. Fluorite, lead sulphide, zinc sulphide, silver, and barite also occur, but in quantities too small to be of economic value.

IRON ORE

Residual deposits of limonite, a hydrous oxide of iron, are distributed widely over the quadrangle. Many of these have in the past been exploited, but all operations were abandoned a good many years ago. The last large mine to cease operations was the Scotia mine, at Scotia, near the southwest corner of the quadrangle. At one time numerous charcoal furnaces were operated along the Bald Eagle Valley and in the vicinity of Bellefonte. All these furnaces except one have been torn down. Centre Furnace, 1 mile northeast of the town of State College, was built as early as 1792 and was probably the first to operate in the region.

Iron ores have been mined in residual deposits on the Stonehenge, Nittany, and Axemann formations, of Beekmantown age; and on the Gatesburg and Warrior formation, of the Upper Cambrian. A very little hematite has been mined in the Clinton formation, of the Silurian. The mines in the Beekmantown formations have all been abandoned for a long time, and it is difficult now to find good exposures showing the relation of the ore to the country rock. The ore occurred mostly as cavern fillings in limestone and as a replacement of impure sandy and clayey limestone, and it was usually called "pipe ore." The deposit at Scotia may be described as typical of this kind of deposit.

The Scotia iron mine was first opened on a large scale by Carnegie Bros., who removed several hundred thousand tons of ore. It was later controlled by Valentine & Co., who continued to work the mine until about 1911, when it was shut down with the exception of the washer, which was employed in rewashing the old dump. Those familiar with the operations of this mine since its opening estimate

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[50] Holland, W. J., A preliminary account of the Pleistocene fauna discovered in a cave opened at Frankstown, Pa.: Carnegie Mus. Annals, vol. 4, pp. 228–233, 1908.

[51] Gidley, J. W., Preliminary report of a recently discovered Pleistocene cave deposit near Cumberland, Md.: U. S. Nat. Mus. Proc., vol. 46, pp. 93–102, 1913.

[52] This chapter was written by Mr. Moore about 1915. Present conditions differ in some particulars.

that about 1,700,000 tons of ore was produced. The workings reached a maximum depth of 75 feet, and the material handled yielded only about 10 to 15 percent of ore.

The ore occurs in a residual mass of clay, sand, gravel, and boulders derived through weathering from interbedded dolomite and sandstone. The dolomite is impure, and on decomposing it leaves a white clay in which irregular masses and concretions of limonite and silica occur. The limonite concretions may be as much as 2 feet in diameter, although most of them are much smaller. Some of them are hollow, and many of the hollow ones, called " bombshell ore ", contain water. Some of the irregular masses of ore taken out weighed several hundred pounds and consisted of nearly pure limonite. Great quantities of chert and flint fragments are mixed with the clay left by the decomposition of the dolomite, and in mining these were removed by crushing and washing the ore. Locally the iron oxide has replaced the dolomite for some distance as a continuous bed. The ore also occurs as a cement in sand and in the brecciated sandstone, although it is difficult to work in this form. The brecciated sandstone seems to be produced by the fracturing of the more rigid sandstone beds, which slump where the interbedded dolomite and the calcite cement in the weaker sandstone beds have been removed in solution.

The iron is believed to have been derived from the pyrite, siderite, and limonite found in the overlying limestones and shales of the Ordovician and later formations, many of which are rich in iron, and to a small extent in the Gatesburg itself. Vast quantities of limestone and dolomite have been eroded from the ore-bearing area, permitting the iron salts to be carried downward. In the Black River, Trenton, and Reedsville rocks, especially the Reedsville, iron pyrite is plentiful, and by oxidation its iron content may be carried to lower levels as sulphate. It would be precipitated as limonite by oxidation or as carbonate through reactions between the sulphate and calcium carbonate in the absence of oxygen. The carbonate thus formed would later be oxidized to hematite or limonite. Much of the iron is no doubt also carried through the agency of organic acids. The fact that ore deposits are found in the limestone above the Gatesburg formation seems to indicate a higher source for much of the iron than the Gatesburg formation itself.

Analyses of the washed ore shipped from the Scotia mine supplied by H. G. Valentine show silica 22 to 26 percent and iron 41 to 46 percent. Analyses made by A. S. McCreath [53] show iron 45.375 to 52.95 percent, manganese 0.208 to 0.403 percent, sulphur 0.056 to

[53] D'Invilliers, E. V., The geology of Centre County: Pennsylvania Second Geol. Survey Rept. T4, p. 222, 1884.

0.123 percent, and water 9.584 to 10.404 percent. These figures are fairly typical for the ores of the whole region.

It seems improbable that any more extensive deposits of iron ore will be found in this quadrangle. Although some small bodies of ore remain, the area has been so well prospected that large bodies are not likely to have been overlooked.

LIMESTONE

Production and uses.—The quarrying of limestone as a source of lime is an active industry in this quadrangle. A great deal of exceptionally pure lime is burned in kilns for chemical and other purposes requiring material of high grade. Much of the lime burned in heaps for agricultural use is of low grade because of the large amount of silica and clayey material it contains. On some farms the better limestone beds are not exposed at the surface, and therefore poorer beds are exploited because the farmer does not go into the business on a sufficiently large scale to justify opening quarries in beds that are not easily accessible.

The best limestone for the production of lime occurs in the Lowville limestone. The Helderberg, Trenton, Axemann, Stonehenge, and Warrior limestones may be used for agricultural lime. The great quarries are all in the Lowville, but the Stonehenge limestone furnishes some good stone for farmers' lime, and some of the more massive beds of the formation supply a considerable proportion of the limestone used for building stone in this quadrangle.

In recent years it has been learned that the dolomites may be burned and the resulting lime and magnesia used on the land to good advantage. This has led to a much greater use than formerly of the Nittany and Bellefonte dolomites for agricultural lime. If farmers are careful to discard the more sandy and clayey portions of these dolomitic formations, the materials may readily be used for burning.

Chemical character.—Many partial analyses of samples from different beds in the Beekmantown limestones and dolomitic limestones have been made by Mr. William Frear, and a few of these follow:

Analyses of samples of limestone, probably from the Axemann limestone

	1	2	3	4
Insoluble in acid	7.06	6.34	10.12	6.31
Al_2O_3 and Fe_2O_3	1.02	1.67	3.28	------
CaO	50.20	50.62	31.48	50.30
MgO	1.03	.64	12.97	2.02
$CaCO_3$	89.59	90.33	56.18	89.76
$MgCO_3$	2.15	1.35	27.21	4.24

1. Half a mile west of Boalsburg.
2. Half a mile southeast of State College.
3. Half a mile north of Bloomsdorf.
4. Three-quarters of a mile southwest of Rock Creamery.

These analyses show that certain portions of these formations are of sufficient purity for good agricultural lime.

Quarry rock.—The "quarry rock", as it is known in this quadrangle, because it is the rock quarried in all the large operations, is a very pure member of the Lowville limestone. (See pls. 8, *A;* 9 *A;* and 12, *B.*) Its thickness ranges from 30 to 90 feet in different parts of the area. It is in some places difficult to obtain an accurate measurement of thickness because the darker limestone, immediately above and below the pure stone, grades into it and has also been quarried and used for flux in the manufacture of steel. The best rock, known as "chemical lime", is mostly drab to light bluish gray, with conchoidal fracture and with conspicuous irregular spots of clear spar. It contains very few fossils, in some quarries none. The quarry bed runs across the quadrangle along the southeast base of Bald Eagle Mountain. It is offset a quarter of a mile by the Bellefonte fault just east of Bellefonte. Almost all the east half of this band of limestone has been opened up by large quarries owned by four different companies. The same bed is exposed on both sides of Pleasant Gap, on the southern limb of the Nittany Valley anticline, where the White Rock quarries are located. The quarry rock at Pleasant Gap is also of high quality, although the "chemical lime" portion is much thinner than at Bellefonte. This high-grade portion has been traced to Lemont, thinning out gradually. The Black River group of limestones, if present, becomes covered by the mountain debris on the southeast side of Nittany Mountain. It is exposed east of this quadrangle and quarried a little at Centre Hall. No trace of the "chemical lime" can be found in the Black River group on the northwest side of Tussey Mountain, but some rock suitable for flux, though difficult to quarry because of its topographic situation, is exposed along the valley at different points.

The beds quarried are so similar in most of the quarries that a description for one place covers almost all localities. The White Rock quarries at Pleasant Gap, just east of the Bellefonte quadrangle, are the only large quarries opened on the Lowville limestone along the northwest side of Nittany Mountain. In these quarries there is about 30 feet of the "chemical lime" rock, which produces a very pure lime. It is overlain by 80 feet of dark-gray thick-bedded limestone, which in many places is nearly glossy on the surface from carbonaceous matter, all of which is used for flux. Beneath the "chemical lime" rock there is near Bellefonte a black shaly seam 4 to 6 inches thick crowded with *Beatricea* and *Tetradium* (pl. 9, *A*), underlying which is 10 feet more of dark limestone used for flux. The larger fragments of the high-grade rock are burned in the kilns, and the "forkings" go to the blast-furnaces.

Along the southeast side of Bald Eagle Mountain near the west side of the quadrangle the whole width of the quarry rock is exposed in but few places. Near the schoolhouse a quarter of a mile southwest of Buffalo Run village 40 feet of the dense, apparently pure limestone is exposed and about 40 feet more of the dark limestone above it. In general it may be said that the band of "chemical lime" rock along the foot of Bald Eagle Mountain averages about 60 feet in thickness. In a quarry east of Coleville the high-grade rock is only 40 feet thick. The amount of furnace rock quarried above or below this differs greatly from place to place.

In the quarry about half a mile northwest of Stevens 59 feet of high-grade limestone, which has conchoidal fracture and is dotted with specks of spar, is being quarried. It underlies a heavy mantle of debris washed down from the mountain. At the base of the quarry rock there is a thin shaly bed. This bed is followed by a footwall of thick beds of blue fossiliferous limestone containing peculiar-shaped solution cavities. The dip of the quarry beds here is 70°. In the quarry directly north of Stevens as much as 80 feet of rock has been removed. There are some clay partings near the base with bands of good rock beneath them. Near the east end there is 56 feet of the high-grade limestone, above which the rock is irregularly bedded, somewhat silicified, and brecciated. The dip here is 60° toward the mountain.

There is a fine series of quarries just above Morris, where the strata dip 60° toward the mountain and the high-grade quarry rock runs about 58 feet in width. Above this high-grade rock is a dark limestone, which is quarried for blast furnaces. Probably the largest quarry in the district is the one northeast of Bellefonte which runs up to the fault zone. The quarry on the north side of the Bellefonte fault shows the widest band of quarry rock in the quadrangle, as about 90 feet of rock is quarried there. Most of this rock is of high grade, but there are a few bands of the furnace rock interbedded. The dip is practically vertical except at the southwest end, where the strata have been overturned a little and dragged out of place during faulting. (See pl. 12, *B*.)

On the northwest border of Bellefonte the quarry bed has been mined underground at a depth of 60 feet below the bottom of the large quarry (pl. 9, *A*). This mine, however, caved in, as sufficient care was not observed in leaving supports for the roof. On the west side of Bellefonte a well-equipped shaft has been sunk in one of the quarries, and preparations have been made for mining limestone on a large scale. At the present time (1933) this mine has been extended to large dimensions, and all the rock used by the American Lime & Stone Co. at Bellefonte for lime burning is taken from it.[54] In connection with this operation, a large modern rotary kiln and a hydrating plant have been built.

The lime made from these quarries is used for glass flux, fertilizers, and plaster, and on account of its great purity much of it is shipped long distances for chemical uses and water purification. Much stone that runs over 90 percent $CaCO_3$ is shipped to Pittsburgh, Emporium, and other places for blast furnaces.

The following analyses of limestone from the quarries of the American Lime & Stone Co. were supplied through the kindness of A. G. Morris, president of the company:

Analyses of limestone from quarries near Bellefonte

[M. M. Morris, analyst]

	1	2	3	4	5	6	7
Insoluble (SiO_2)	1.02	0.36	1.30	2.70	3.72	0.48	2.20
Iron and alumina (R_2O_3)	.24	.16	.26	.86	.88	.26	.30
$CaCO_3$	97.81	98.43	96.45	94.10	91.90	98.42	96.20
$MgCO_3$	.93	1.05	1.99	2.34	3.50	.84	1.30
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1–4. Quarry 22, near Bellefonte.
5–7. Quarry 13, near Bellefonte.

The average of 13 samples from two quarries shows 96.15 percent of $CaCO_3$.

Cement materials.—There is plenty of high-calcium limestone in this quadrangle suitable for the manufacture of portland cement, but no plants have yet been established. No deposits have been found so near a deposit of shale that the two rocks could be used together economically, and no deposit of shaly limestone of suitable composition for the manufacture of natural portland cement has been discovered.

In the Bellefonte dolomite, just above the sand bed in that formation, there is some dense bluish-gray extremely fine grained dolomite, which weathers white on the surface and breaks with a marked conchoidal fracture. It has a siliceous appearance, and an analysis shows that its composition is similar to that of some natural or hydraulic lime cements. An analysis gave the following percentages:

Analysis of Bellefonte dolomite

[W. A. Royce, analyst]

SiO_2	15.25	MgO	18.12
Fe_2O_3	.72	Loss on ignition	37.49
Al_2O_3	3.35	$CaCO_3$	44.68
CaO	25.02	$MgCO_3$	38.07

[54] For details concerning this operation see Miller, B. L., Limestones of Pennsylvania: Pennsylvania Top. and Geol. Survey Bull. M7, pp. 150–151, 1925.

BUILDING AND GLASS SAND

Considerable quantities of building sand are obtained from the Gatesburg formation, especially near Scotia, and shipped to the neighboring towns. The sand is of good quality for mixing with cement and for mortar. Lesser quantities are also obtained for local use from disintegrated Oriskany sandstone. Some of this sand was formerly dug near Milesburg for glass manufacture, but the enterprise has been abandoned in this locality, although there are pits near Curtin, a few miles northeast of Milesburg. Most of the sand in this formation is not sufficiently free from iron and alumina for use as a glass sand.

GANISTER

The term "ganister" is used rather loosely in this country both for the silica rock that is ground and mixed with a refractory clay bond for plastering the interior of furnaces and for the quartzite that is crushed for the manufacture of silica brick. Strictly, ganister is a refractory mixture of silica and clay, with the clay in the proper proportions to make a suitable bond for the silica. The name was first used in England for a rock in the Coal Measures that is of such a composition that it can be used, after crushing, for plastering furnaces. In Pennsylvania the rock used in the manufacture of silica brick and ganister comes chiefly from the Tuscarora quartzite, which is distributed widely through the mountains of the State. So far no silica-brick plant has been erected within the Bellefonte quadrangle. A large amount of material has been removed from the slide rock on Bald Eagle Mountain, on the northeast edge of the Milesburg gap, but the operation was abandoned after about 2 years' work. This rock, according to reports, was shipped for the manufacture of ganister. There is undoubtedly a large amount of the Tuscarora quartzite in the Bellefonte quadrangle that could be used in the manufacture of silica brick, but the material on the whole is not of as good quality as that near Hollidaysburg, Alfaretta, Mount Union, and the other silica-brick centers. The formation is a little higher in iron and alumina in the Bellefonte region and to the east than it is to the southwest, and these constituents are detrimental. The iron should preferably not exceed 2 percent on the average, and the alumina 1 percent. The silica should exceed 96 percent, and lime and alkalies should be low. The slide rock is a little better for silica brick than the solid formation, because the clay has weathered from it and the more soluble constituents have been removed in solution. It is also cheaper to quarry the slide rock than the ledge rock. The outcrops of the Tuscarora in the mountain ridges are, however, admirably located for quarrying.

BUILDING STONE

The Bellefonte quadrangle contains a large quantity and a considerable variety of stone that can be used for rough building stone, such as foundations, fence walls, and similar structures. Sandstone for such purposes may be obtained from the Pocono, Catskill, Chemung, Portage, Juniata, and Oswego formations. Some of the material from the Catskill, Juniata, and Oswego is of fine color and dresses well for better grades of building material, but few extensive, uniform bodies of such rock can be found. Most of the Catskill and Juniata rock is too soft, and the color and other physical properties are also, as a rule, too variable. Limestone is used in large quantities for building stone, and it is obtained from the strata that have not been excessively fractured in the folding of the region—for example, on the south side of the Nittany Valley anticline. Much stone has been obtained from the Stonehenge, Nittany, Axemann, Bellefonte, and Black River formations. Some of the best-appearing stone, especially that from the lower part of the Lowville, contains considerable pyrite, which under some conditions is an injurious ingredient, as it may oxidize to sulphuric acid, which dissolves the stone, and to limonite, which discolors it. The Bellefonte and Nittany dolomites weather to a gray which is too light to make a first-class stone for some types of houses, whereas the Black River limestones and some of the Stonehenge limestone is too dark at first, although it weathers to a less dull and somber hue.

LEAD, ZINC, SILVER, AND BARITE

Lead, zinc, silver, and barite are known to be present in the Bellefonte quadrangle, but all occur in quantities so small that they are not of commercial interest. In the ganister quarry in the Tuscarora quartzite in the Milesburg Gap a small vein was dicovered that contains galena, pyromorphite, ruby sphalerite, barite, pyrite, and a little silver in some unidentified form, no doubt enclosed in galena.

This vein is about 6 inches wide and cuts diagonally across the bedding near the base of the mountain. The walls are not very distinct, and there is considerable clay selvage. The gangue consists of clay and barite. A little pyromorphite was found on the oxidized surface of the vein. The deposit has the appearance of having been concentrated by meteoric waters percolating through the sandstone and collecting the metals in a fissure and along the bedding planes of the sandstone. Barite was found in small quantities in several other places in the ganister quarry. It occurs as irregular masses in the sandstone. There have been various reports regarding the presence of silver in the lead and zinc, but an assay of one of the most promising looking specimens gave only 0.34 ounce to the ton. A drift was run into the hill for a distance of 50 feet, but without promising results.

FLUORITE AND PYRITE

Purple and violet fluorite occurs in small quantities in little stringers, a fraction of an inch thick and a few inches long, in the Cambrian and Ordovician limestones. Pyrite occurs in a disseminated condition in several of the formations, but not in commercial quantities.

CLAYS

Brick clays.—The clays worked in this quadrangle are used for the manufacture of brick and tile. Near Struble the clay from an abandoned iron-ore washer has been used in the manufacture of red building brick, but it makes a comparatively soft brick that has been used mostly for filling. On Moose Run, three-quarters of a mile above Central City, there is a quarry in Brallier shale where materials are obtained for red brick and hollow tile. At a brick plant on the north side of Central City this shale is ground and mixed with alluvial clay from the valley of Bald Eagle Creek. This alluvial clay occurs in a fan at the mouth of Moose Run and consists chiefly of the materials eroded from the Chemung and Portage shales. Similar clay deposits occur at the mouths of several of the runs that enter Bald Eagle Valley, and there is a great deal of shale in the Brallier that could be mixed with alluvial clays present along the northwest side of Bald Eagle Creek and utilized for red brick and tile.

White clay.—In an old ore pit 2 miles west of Scotia there is a deposit of white clay, but as all the material in sight has been dug from the bottom of a pit now filled with water, there is no definite evidence of its extent. The owner of the property, Mr. F. P. Blair, of Bellefonte, states that large bodies of clay have been proved by drilling. The clay probably occurs in pockets in the bedded rocks, and the deposit is probably very irregular, like other deposits of this clay in the Gatesburg formation. It is a residual deposit in the Gatesburg formation, having been derived from the clay originally in the finer layers of the sandstone and in dolomite beds. Similar deposits are worked in this formation near Furnace Road station, a few miles west of the Bellefonte quadrangle, and at Mines, in Blair County. A large number of smaller deposits of the same type occur in association with the limonite deposits in the Gatesburg. Clay of this type has been used after washing in the manufacture of paper and could be used in the manufacture of whiteware and tile. It is very plastic and burns nearly white.

WATER RESOURCES

Surface water.—The Bellefonte quadrangle is well watered by numerous spring-fed creeks, most of which have their origin either at the base of the Pocono formation or in the Catskill formation, the Juniata formation, or the Ordovician limestones. Among these may be mentioned Bald Eagle and Spring Creeks, Buffalo Run, and Logan Branch.

Ground water.—The underground circulation is very extensive, and sink holes are developed on a large scale, especially in the purer limestones. The stream that formerly flowed in Big Hollow now runs underground, probably to the large spring near Rock. Much of the drainage from The Barrens must issue in Thompson Spring, half a mile northeast of State College, and the stream that disappears at the foot of McBride Gap evidently comes to the surface again in the springs below Pleasant Gap. The large spring at Bellefonte apparently has its source in the drainage of a considerable area along the south flank of Bald Eagle Mountain.

In The Barrens many farmers depend upon rain water, although water is found almost anywhere if drilling is carried to a depth of about 400 feet. The height of the water-bearing beds above sea level differs from place to place because of the many alternations of sandstone and dolomite beds that compose the Gatesburg formation.

Two wells have been drilled at Scotia. One is 583 feet deep, and the water is said to rise about 60 feet in the well. The record of the other, the top of which is about 25 feet lower in altitude, follows:

Log of deep well at Scotia

	Thickness	Depth		Thickness	Depth
	Feet	*Feet*		*Feet*	*Feet*
Clay and soft sandrock	80	80	Hard white sandrock	12	192
Solid blue flintrock	13	93	Soft yellow shaly sandrock	135	327
Hard white flint and sandrock	12	105	Soft yellow clay	40	367
Soft yellow shaly sandrock	75	180	Hard limestone and sandrock	37	404

Drilling was continued 25 feet after water was struck.

A well 1½ miles north-northeast of Scotia was drilled to a depth of 160 feet and contains about 18 feet of water. The position of the dolomite members in the Gatesburg formation indicates that one of the thick dolomite beds is the water-bearing stratum. Another well near the sawmill at Altro, ending in rock called "limestone" by the drillers, is 438 feet deep. Water was struck at 190 feet, and apparently no water was found below that depth. After being torpedoed at 190 feet the well flowed 25 gallons a minute. This yield makes it evident that adequate water is available in almost any part of The Barrens if drilling is carried a few hundred feet to one of the massive dolomite beds.

Several wells have been drilled in the solid dolomite in the vicinity of State College and Lemont, and plenty of water is found, in most wells within 100 feet of the surface. A diamond-drill core 8 inches in diameter and 330 feet long, consisting of dolomite throughout, was taken from the well at the Pennsylvania State College. This well by pumping furnishes large quantities of water at all times of the year.

Municipal supplies.—Most of the towns and villages in the quadrangle obtain their water supplies from springs. Bellefonte obtains water from a large spring within the town limits, which has a flow of 14,600 gallons a minute. Boalsburg procures its water from the creek that issues from Galbraith Gap, and State College is supplied from reservoirs on spring creeks in Hasson and Mussers Gaps, in Tussey Mountain. The supply at present available for State College is not sufficient for the rapidly growing needs of the town. An adequate supply must be provided in the near future by the construction of a larger reservoir in Hasson Gap, by pumping water over the second ridge of Tussey Mountain from the creek on the south side, by procuring part of the supply in Galbraith Gap, or by drilling wells in the vicinity of the town and pumping the water up to a reservoir. By drilling through the limestone and dolomite into Gatesburg sandstone the water that would thus be obtained should be filtered sufficiently to be free from contamination. If a dam were to be constructed in Hasson Gap it should be placed across the gap from one ledge to another of the Oswego sandstone, and great care should be exercised in obtaining a proper bearing for its ends and bottom so that it would not leak. Pressure grouting of cracks might be necessary. The abundant supply issuing from Thompson Spring, half a mile northeast of State College, has not been utilized because of the cost of pumping and the danger of contamination by sewage from the village above. Evidence of contamination is increasing in the greater percentage of nitrates found now than in former analyses. This spring flows during the summer about 2,625 gallons a minute.

The apparent evidence of contamination of the water of Thompson Spring is an excellent example of conditions that generally exist where circulating ground water has produced open channels in limestone. The limestone is readily dissolved along joints and bedding planes by water containing carbon dioxide, and thus large and small cavities are produced through which the water flows as in a pipe—that is, without any opportunity for self-purification by filtration as in sand or gravel. Consequently any polluting material that may enter the underground system in the vicinity of sink holes is likely to be carried rapidly through the limestone channels to the springs. Springs that by their large volume and low pressure indicate circulation in cavernous limestone should never be utilized as sources of water supply until careful tests have demonstrated the absence of immediate connection with sources of dangerous contamination. Such tests are usually made by introducing powerful dyes into the underground circulation at suspected points of pollution.

SOILS

The soils of the Bellefonte quadrangle consist entirely of residual materials from the rocks of the region, and in most places, except on the mountain slopes, almost entirely from the rocks that immediately underlie the soils. There is thus a very close relation between the distribution of the soils and of the rock formations of the quadrangle. This condition is therefore in contrast to that found in glaciated areas in some parts of Pennsylvania, where most of the soil has been transported long distances by the glaciers.

The most productive soils are those derived from the limestones and dolomites, but even these require a good deal of lime, or crushed limestone, to " sweeten " the soils made " sour " when the calcareous materials have been removed in solution.

The Gatesburg formation produces a very sandy soil, which is too acid and in dry seasons too arid for agricultural use, although a few fairly good farms lie within the borders of this formation, on the interbedded dolomite strata. Owing to the poor quality of the soil in the region underlain by this formation the area is locally known as " The Barrens ", and little attempt is made to farm it.

The Mines dolomite produces in many places a good soil, but most of it is acid and very stony, owing to the vast amount of chert which it contains. The same statement may be made concerning parts of the lower portion of the Nittany dolomite which carries a great deal of chert and some sandy beds. The other dolomites and limestones carry less silica.

The Reedsville shale leaves a fair soil where it is not too high in iron and not too deeply covered with sandy wash from the mountains. The soil from the Juniata is farmed, but it is dry and high in iron. Most of the farms which were taken up on this formation in the earlier days of the settlement of the region have been abandoned. The residual materials from the Hamilton and Marcellus shales and from parts of the Portage and Chemung shales make good soils. On account of its topographic position, the Chemung formation tends to wash too rapidly and to leave a surface covered with fragments of shale and fine-grained sandstone. The Catskill formation leaves fairly good soil where there is not too much sandstone and where topographic conditions are favorable. Much of its area is favorable for fruit culture.

The Oswego, Tuscarora, Pocono, Mauch Chunk, Pottsville, and parts of the Oriskany, Portage, Chemung, and Catskill formations have remained in forest, as they produce a poor soil. Tussey Mountain is set aside as a portion of the State forest reserve.

The area covered with alluvium along the streams, outside of the Bald Eagle Valley, is comparatively small in this region. The soil is, however, of good quality.

The soils of Centre County, in which the Bellefonte quadrangle lies, have been mapped and described elsewhere.[55]

[55] Soil survey Centre County, Pa., U. S. Dept. Agr., 1910.

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