DEPARTMENT OF THE INTERIOR
RAY LYMAN WILBUR, SECRETARY

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

225

GEOLOGIC ATLAS
OF THE
UNITED STATES

FAIRFIELD-GETTYSBURG FOLIO

PENNSYLVANIA

BY

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WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER
1929

GEOLOGIC ATLAS OF THE UNITED STATES.

UNITS OF SURVEY AND OF PUBLICATION.

The Geological Survey is making a topographic and a geologic atlas of the United States. The topographic atlas will consist of maps called *atlas sheets*, and the geologic atlas will consist of parts called *folios*. Each folio includes topographic and geologic maps of a certain four-sided area, called a *quadrangle*, or of more than one such area, and a text describing its topographic and geologic features. A quadrangle is limited by parallels and meridians, not by political boundary lines, such as those of States, counties, and townships. Each quadrangle is named from a town or a natural feature within it, and at the sides and corners of each map are printed the names of adjacent quadrangles.

SCALES OF THE MAPS.

On a map drawn to the scale of 1 inch to the mile a linear mile on the ground would be represented by a linear inch on the map, and each square mile of the ground would be represented by a square inch of the map. The scale may be expressed also by a fraction, of which the numerator represents a unit of linear measure on the map and the denominator the corresponding number of like units on the ground. Thus, as there are 63,360 inches in a mile, the scale 1 inch to the mile is expressed by the fraction $\frac{1}{63,360}$, or the ratio 1:63,360.

The three scales most commonly used on the standard maps of the Geological Survey are 1:31,680, 1:62,500, and 1:125,000, 1 inch on the map corresponding approximately to one-half mile, 1 mile, and 2 miles on the ground. On the scale of 1:31,680 a square inch of map surface represents about one-fourth of a square mile of earth surface; on the scale of 1:62,500, about 1 square mile; and on the scale of 1:125,000, about 4 square miles. In general a standard map on the scale of 1:125,000 represents one-fourth of a "square degree"—that is, one-fourth of an area measuring 1 degree of latitude by 1 degree of longitude; one on the scale of 1:62,500 represents one-sixteenth of a "square degree"; and one on the scale of 1:31,680 represents one-sixty-fourth of a "square degree." The areas of the corresponding quadrangles are about 1,000, 250, and 60 square miles, though they differ with the latitude, a "square degree" in the latitude of Boston, for example, being only 3,525 square miles and one in the latitude of Galveston being 4,150 square miles.

FEATURES SHOWN ON THE TOPOGRAPHIC MAPS.

The features represented on the topographic maps comprise three general classes—(1) inequalities of surface, such as plains, plateaus, valleys, hills, and mountains, which collectively make up the *relief* of the area; (2) bodies of water, such as streams, lakes, swamps, tidal flats, and the sea, which collectively make up the *drainage*; (3) such works of man as roads, railroads, buildings, villages, and cities, which collectively are known as *culture*.

Relief.—All altitudes are measured from mean sea level. The heights of many points have been accurately determined, and those of some are given on the map in figures. It is desirable, however, to show the altitude of all parts of the area mapped, the form of the surface, and the grade of all slopes. This is done by contour lines, printed in brown, each representing a certain height above sea level. A contour on the ground passes through points that have the same altitude. One who follows a contour will go neither uphill nor downhill but on a level. The manner in which contour lines express altitude, form, and slope is shown in figure 1.

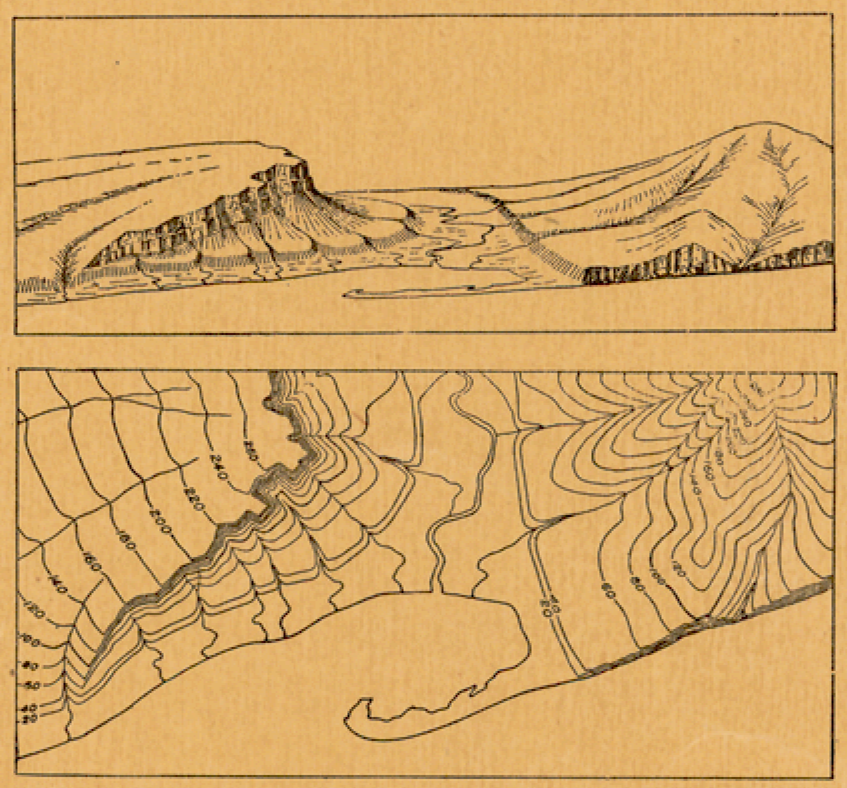

FIGURE 1.—Ideal view and corresponding contour map.

The view represents a river valley between two hills. In the foreground is the sea, with a bay that is partly inclosed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle upward slope; that on the left merges into a steep slope that passes upward to a cliff, or scarp, which contrasts with the gradual slope back from its crest. In the map each of these features is indicated, directly beneath its position in the view, by contour lines. This map does not include the distant part of the view.

As contours are continuous horizontal lines they wind smoothly about smooth surfaces, recede into ravines, and project around spurs or prominences. The relations of contour curves and angles to the form of the land can be seen from the map and sketch. The contour lines show not only the shape of the hills and valleys but their altitude, as well as the steepness or grade of all slopes.

The vertical distance represented by the space between two successive contour lines—the contour interval—is the same, whether the contours lie along a cliff or on a gentle slope; but to reach a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep slopes.

The contour interval is generally uniform throughout a single map. The relief of a flat or gently undulating country can be adequately represented only by the use of a small contour interval; that of a steep or mountainous country can generally be adequately represented on the same scale by the use of a larger interval. The smallest interval commonly used on the atlas sheets of the Geological Survey is 5 feet, which is used for regions like the Mississippi Delta and the Dismal Swamp. An interval of 1 foot has been used on some large-scale maps of very flat areas. On maps of more rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used, and on maps of great mountain masses like those in Colorado the interval may be 250 feet.

In figure 1 the contour interval is 20 feet, and the contour lines therefore represent contours at 20, 40, 60, and 80 feet, and so on, above mean sea level. Along the contour at 200 feet lie all points that are 200 feet above the sea—that is, this contour would be the shore line if the sea were to rise 200 feet; along the contour at 100 feet are all points that are 100 feet above the sea; and so on. In the space between any two contours are all points whose altitudes are above the lower and below the higher contour. Thus the contour at 40 feet falls just below the edge of the terrace, and that at 60 feet lies above the terrace; therefore all points on the terrace are shown to be more than 40 but less than 60 feet above the sea. In this illustration all the contour lines are numbered, but on most of the Geological Survey's maps only certain contour lines—say every fifth one, which is made slightly heavier—are numbered, for the heights shown by the others may be learned by counting up or down from these. More exact altitudes for many points are given in bulletins published by the Geological Survey.

Drainage.—Watercourses are indicated by blue lines. The line for a perennial stream is unbroken; that for an intermittent stream is dotted; and that for a stream which sinks and reappears is broken. Lakes and other bodies of water and the several types of marshy areas are also shown in blue.

Culture.—Symbols for the cultural features and for public-land land lines and other boundary lines, as well as all the lettering and the map projection, are printed in black.

FEATURES SHOWN ON THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic map as a base, the distribution of rock masses on the surface of the land and, by means of structure sections, their underground relations so far as known, in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or *magma*, within these channels—that is, below the surface—are called *intrusive*. An intrusive mass that occupies a nearly vertical fissure which has approximately parallel walls is called a *dike*; one that fills a large and irregular conduit is termed a *stock*. Molten material that traverses stratified rocks may be intruded along bedding planes, forming masses called *sills* or *sheets* if they are relatively thin and *laccoliths* if they are large lenticular bodies. Molten material that is inclosed by rock cools slowly, and its component minerals crystallize when they solidify, so that intrusive rocks are generally crystalline. Molten material that is poured out through channels that reach the surface is called *lava*, and lava may build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and contain, especially in their outer parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows are also usually made porous by the expansion of the gases in the magma. Explosions due to these gases may accompany volcanic eruptions, causing the ejection of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic material deposited in lakes and seas, or of material deposited in such bodies of water by chemical precipitation or by organic action are termed *sedimentary*.

The chief agent in the transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits they form are called mechanical. Such deposits are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. Some of the materials are carried in solution, and deposits composed of these materials are called organic if formed with the aid of life or chemical if formed without the aid of life. The more common rocks of chemical and organic origin are limestone, chert, gypsum, salt, certain iron ores, peat, lignite, and coal. Any one of the kinds of deposits named may be formed separately, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind, and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is *loess*, a fine-grained earth; the most characteristic of the glacial deposits is *till*, a heterogeneous mixture of boulders and pebbles with clay or sand.

Most sedimentary rocks are made up of layers or beds that can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be *stratified*.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks with reference to the sea, and shore lines are thus changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land surface is in fact composed of rocks that were originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate, and their more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. The upper parts of these deposits, which are occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a considerable admixture of organic matter.

Metamorphic rocks.—In the course of time and by various processes rocks may become greatly changed in composition and texture. If the new characteristics are more pronounced than the old the rocks are called *metamorphic*. In the process of metamorphism the chemical constituents of a rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressure, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structural features may have been lost entirely and new ones substituted. A system of parallel planes along which the rock can be split most readily may have been developed. This acquired quality gives rise to *cleavage*, and the cleavage planes may cross the original bedding planes at any angle. Rocks characterized by cleavage are called *slates*. Crystals of mica or other minerals may have grown in a rock in parallel arrangement, causing lamination or foliation and producing what is known as *schistosity*. Rocks that show schistosity are called *schists*.

As a rule, the older rocks are most altered and the younger are least altered, but to this rule there are many exceptions, especially in regions of igneous activity and complex structure.

GEOLOGIC FORMATIONS.

For purposes of geologic mapping the rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, an alternation of shale and limestone. If the passage from one kind of rocks to another is gradual it may be necessary to separate two contiguous formations by an arbitrary line, and the distinction between some such formations depends almost entirely on the fossils they contain. An igneous formation contains one or more bodies of one kind of rock of similar occurrence or of like origin. A metamorphic formation may consist of one kind of rock or of several kinds of rock having common characteristics or origin.

[Continued on inside back cover.]

DESCRIPTION OF THE FAIRFIELD AND GETTYSBURG QUADRANGLES

By George W. Stose and F. Bascom[1]

INTRODUCTION

LOCATION AND AREA

The Fairfield and Gettysburg quadrangles are in the south-central part of Pennsylvania, between parallels 39° 45′ and 40° and meridians 77° and 77° 30′, and together contain about 458 square miles. They embrace the larger part of Adams County, the east side of Franklin County, and the south corner of Cumberland County. The southern border of the area is within 2 miles of the Maryland State boundary. (See fig. 1.)

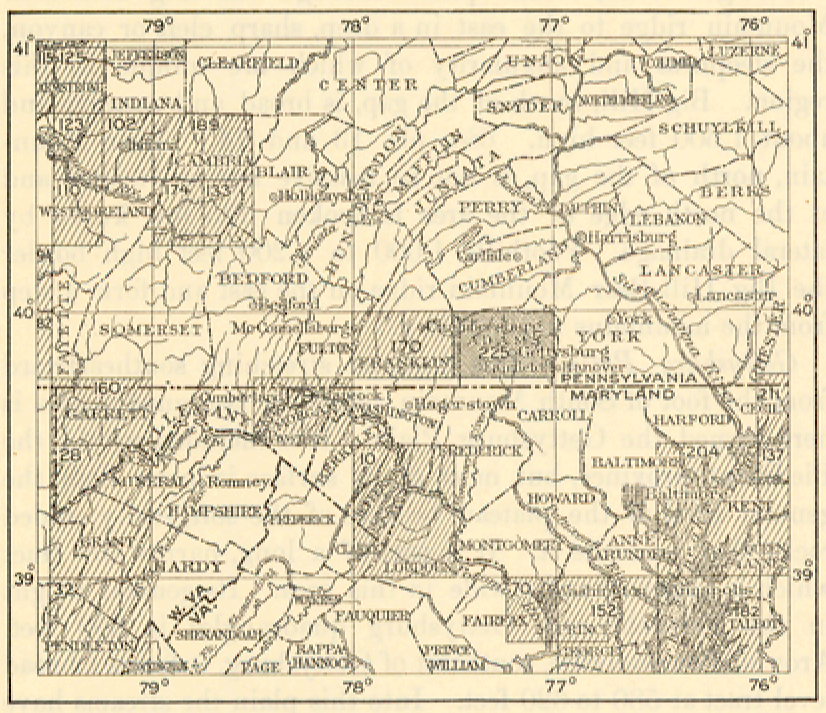

FIGURE 1.—Index map of south-central Pennsylvania and portions of adjacent States

The location of the Fairfield and Gettysburg quadrangles is shown by darker ruling (No. 225). Published folios describing other quadrangles are indicated by lighter ruling and are listed on the back cover of this folio

APPALACHIAN HIGHLANDS

These quadrangles form part of the major physiographic division known as the Appalachian Highlands, which lies between the Atlantic Plain on the east and the Interior Plains on the west and extends from central Alabama to Canada. This region had throughout its extent a similar physiographic and geologic history, which is recorded in its rocks and in its topographic features. Only a part of this history can be interpreted from so small an area as the Fairfield and Gettysburg quadrangles, and it is therefore desirable to consider the area in its relation to the entire division.

The Appalachian Highlands include three well-marked longitudinal subdivisions, each characterized by a general similarity of sedimentary deposits, geologic structure, and topography. The western subdivision includes the Appalachian Plateaus; the middle subdivision is the Appalachian Valley and Ridges province; the eastern subdivision includes the Blue Ridge and Piedmont provinces. Topographically the Blue Ridge and Piedmont provinces are distinct, but geologically they are so closely allied that they may be better treated as a unit. These three subdivisions are well defined from Alabama to southern New York, and the following description applies chiefly to that part of the Appalachian Highlands. (See fig. 2.) Farther north and east are the St. Lawrence Valley, Adirondack, and New England provinces.

APPALACHIAN VALLEY AND RIDGES

The middle subdivision has generally been called the Appalachian Valley province, but in most places, especially in Pennsylvania, ridges form so large a part of it that the name Appalachian Valley and Ridges is more appropriate, and that name was proposed by the writer and has been adopted by the United States Geological Survey. It is the most uniform and best defined of the three, being sharply delimited on the southeast by the Blue Ridge province and on the northwest by the Appalachian Plateaus. In its southern portion it coincides with the belt of closely folded and faulted rocks that form the Coosa Valley of Alabama and Georgia and the valley of east Tennessee and Virginia; this portion ranges in width from 40 to 125 miles. Throughout its central and northern portions only the east side of the province is marked by great valleys; these range in width from 8 to 13 miles and comprise the Shenandoah Valley of Virginia, the Cumberland Valley of Maryland and southern Pennsylvania, the Lebanon Valley of eastern Pennsylvania, and the Kittatinny Valley of New Jersey. The west side of this part of the province throughout most of its extent is a succession of narrow longitudinal valleys separated by long parallel ridges. Its general altitude, however, is markedly lower than that of the mountainous provinces on both sides.

The rocks of the Appalachian Valley and Ridges are almost wholly sedimentary and consist of limestone, shale, and sandstone. The strata were deposited in nearly horizontal layers, but they are now inclined at various angles, and their outcrops form narrow belts of the different kinds of rock. The surface relief depends upon the differences in hardness and solubility of the outcropping rocks. In the southern part of the province, owing to the absence of some of the resistant sandstones that occur farther north and to the correspondingly larger amounts of calcareous and shaly rocks which are brought up in the anticlinal folds and exposed by erosion, the surface has been more readily worn down and is lower and generally less varied than that of the adjacent mountain and plateau provinces. This is true likewise of the northeastern part of the Appalachian Valley and Ridges province, but in its northwestern part high, sharp-crested parallel ridges and intervening valleys follow the narrow belts of upturned hard and soft rocks respectively.

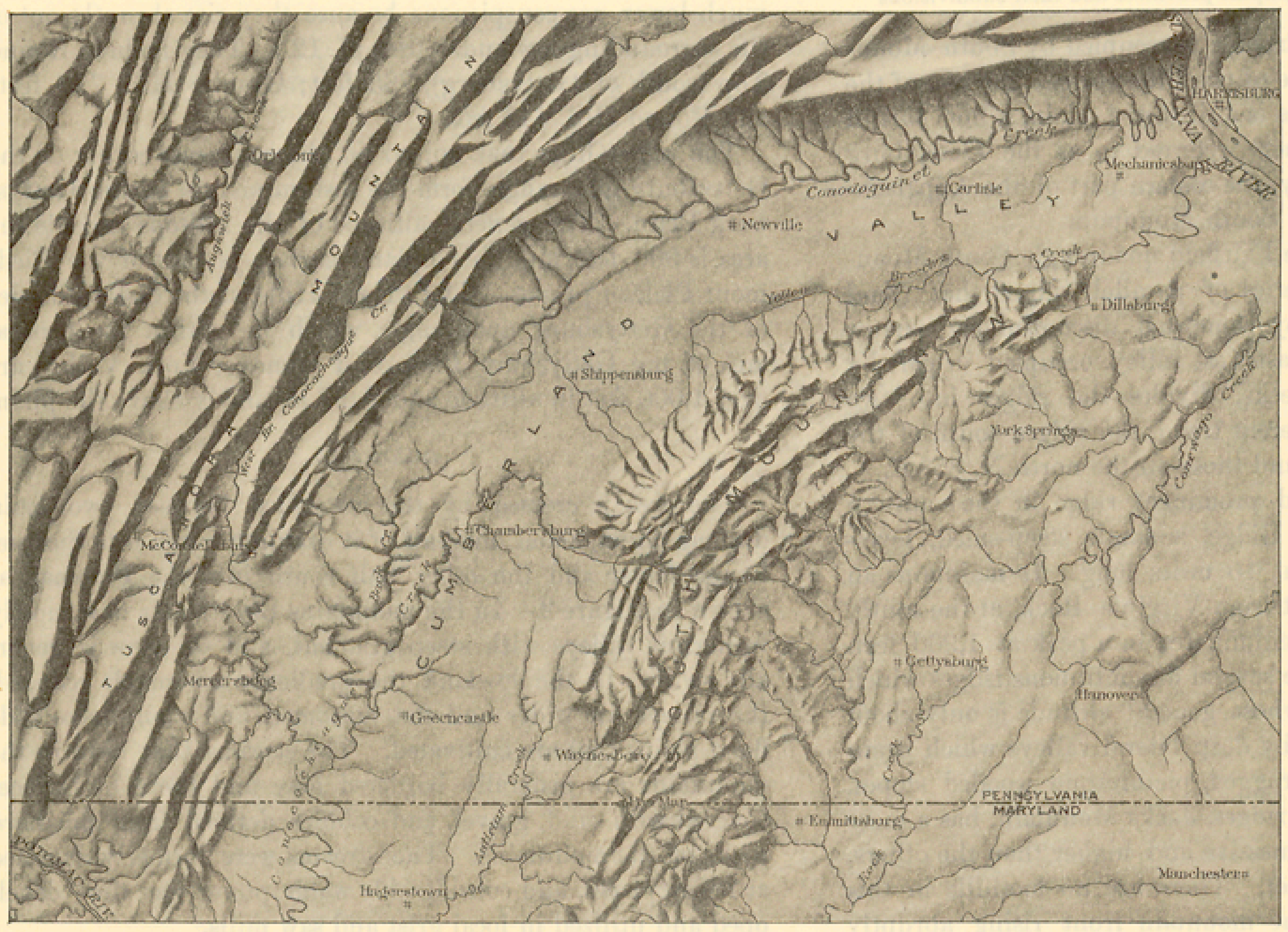

FIGURE 2.—Relief map of part of southern Pennsylvania showing mountain ridges, valleys, and drainage systems

The Fairfield and Gettysburg quadrangles include the eastern part of South Mountain and the area to the east as far as Hanover and extend from a line a little north of the State boundary northward nearly to York Springs

BLUE RIDGE AND PIEDMONT PROVINCES

The eastern subdivision of the Appalachian Highlands embraces the Blue Ridge and Piedmont provinces. The Blue Ridge comprises many minor ridges, which, under local names, extend from southeastern New York to northern Georgia. Chief among these are the Highlands of southeastern New York and New Jersey, 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 Blue Ridge in Georgia.

The Piedmont province is a wide belt of upland southeast of the Blue Ridge province. It descends gently southeastward and grades into the Coastal Plain, which borders the Atlantic Ocean. The Blue Ridge and Piedmont provinces grade into each other in places, with no sharp boundary. The form of the surface differs largely in accordance with the proximity of large trunk streams and their activity in wearing down the rocks. The rocks of this subdivision are largely crystalline, being either sediments that have been metamorphosed to quartzite, slate, schist, and gneiss, or igneous rocks that have solidified from a molten condition, such as granite, diorite, gabbro, rhyolite, and basalt, also more or less altered by metamorphism.

APPALACHIAN PLATEAUS

The western subdivision of the Appalachian Highlands comprises the Cumberland and Allegheny Plateaus and several lower plateaus in Tennessee, Kentucky, and Ohio. On the west it is bordered mainly by the Interior Low Plateaus and Central Lowland provinces of the Interior Plains. Its eastern border is sharply defined in most places by the Allegheny Front and the Cumberland escarpment.

The rocks of this subdivision are almost entirely sedimentary and are but gently folded. The form of the surface, which is in part dependent on the character and attitude of the rocks, is that of plateaus in various stages of dissection. In the southern half of the province large portions of the plateau country are very flat, but more commonly the plateaus are dissected by many valleys and ravines into numerous small, flat-topped hills. In portions of West Virginia and Pennsylvania the plateau surface is so largely dissected as to leave irregular rounded knobs and ridges that bear little resemblance to the original flat surface. The western part of the province has been extensively eroded, and portions of its surface are of much lower altitude but are still comparatively level or rolling.

ALTITUDE

The Appalachian Highlands attain their greatest height in North Carolina, where Mount Mitchell, in the Blue Ridge province, reaches an altitude of 6,711 feet. From this culminating point the mountains descend to less than 1,000 feet at the south end of the province in Alabama. The highest mountain in Virginia is Mount Rogers, in the Blue Ridge, which is 5,719 feet above sea level. The valley ridges in Virginia reach over 4,700 feet, but in Maryland and Pennsylvania they do not rise above 2,200 feet. The plateau province, west of the Appalachian Valley, has at its southern limit an altitude of 500 feet, ascends to 2,000 feet in Tennessee, reaches 4,000 feet in eastern Kentucky, and culminates at 4,800 feet in West Virginia, whence it descends again to 3,300 feet in Maryland and 2,200 feet in north-central Pennsylvania.

The height of the floor of the Appalachian Valley is determined largely by the drainage basins of the trunk streams that cut through the mountain barriers on each side at irregular intervals, and it has therefore numerous culminating points on the watersheds between these streams. Thus it rises from less than 500 feet in Alabama to 2,700 feet on the divide between Tennessee and New Rivers in Virginia, whence it descends to 2,200 feet in the New River valley. It rises and falls likewise over the divides and into the valleys of James and Potomac Rivers in Virginia, declining to 500 feet in the Potomac Basin. In Pennsylvania the floor of the valley does not rise above 1,000 feet. Throughout the length of the province the stream channels are cut 50 to 250 feet below this valley floor, and the ridges rise 500 to 2,000 feet above it.

DRAINAGE

The drainage of the Appalachian Highlands south of New York flows in part eastward to the Atlantic Ocean, in part southward to the Gulf of Mexico, and in part westward to Mississippi River. The greater part of the Appalachian Plateaus is drained by streams flowing westward to Ohio River.

[1] The descriptions are chiefly by G. W. Stose; the description of the pre-Cambrian rocks is by F. Bascom and G. W. Stose, and the petrographic portion by F. Bascom.

The northern portion of the Blue Ridge province is drained eastward to the Atlantic, but south of New River all except the eastern slope is drained westward to the Ohio by tributaries of the Tennessee or southward to the Gulf by tributaries of the Coosa.

In general the streams of the Appalachian Valley and Ridges province flow for long distances in the lesser valleys along the outcrops of softer rocks parallel to the mountain ranges. These longitudinal streams empty into large transverse rivers, which cross one or the other of the mountain barriers. From the northern portion of the province Delaware, Susquehanna, Potomac, James, and Roanoke Rivers pass through the Blue Ridge and Piedmont provinces in narrow gaps or gorges and flow eastward to the sea. In the central portion, in Virginia, the longitudinal streams form New River, which flows westward in a deep, narrow gorge through the Allegheny Plateau to Ohio River. In southwestern Virginia and Tennessee the Appalachian Valley is drained by tributaries of Tennessee River, which at Chattanooga leaves the broad valley and, entering a gorge through the Cumberland Plateau, flows westward to the Ohio. Farther south the streams flow directly to the Gulf of Mexico.

GENERAL GEOLOGY

The rocks that appear at the surface of the Appalachian Highlands comprise sedimentary rocks, igneous rocks, and certain other crystalline rocks which, on account of their age and extensive alteration, are of uncertain origin. The geologic history of the region is preserved in these rocks, but at no one place is the record complete. Only by combining the facts obtained from different parts of the region can the general sequence of geologic events be determined.

The oldest rocks of the region consist largely of gneisses and schists and occur chiefly in the Piedmont province. The original character of most of these rocks is entirely obliterated by the extensive alteration that has taken place during the long ages since their formation. Some were undoubtedly sediments laid down in the earliest seas, and others were ancient deep-seated intrusive masses. The great pressure and heat to which these rocks were subjected while deeply buried in the earth recrystallized them, and they now possess a gneissoid or schistose structure. The igneous rocks are mostly granite, diorite, and gabbro. This complex of ancient rocks is regarded as belonging to the Archean period.

After the uplift and erosion of these deep-seated rocks lavas were poured out upon them. These ancient extrusive rocks and the associated sedimentary schist, which are most common in the Piedmont province, are believed to be of Algonkian age. They are separated from the overlying Cambrian strata by an unconformity, and their fragments form basal conglomerates in the Cambrian. In general, the oldest rocks appear at the surface on the east side of the region, and successively younger strata appear toward the west.

After a period of uplift and erosion a portion of the Appalachian continent was submerged beneath the sea, and there sand, gravel, mud, and calcareous ooze were successively laid down in the form of marine sediments. In these deposits, which are now hardened to sandstone, conglomerate, shale, and limestone, can be seen fragments of waste from the igneous and metamorphic rocks of the adjacent land. The sea in which these sediments were laid down occupied a shallow basin in the interior of the American continent, and its eastern shore shifted back and forth in the Appalachian Highlands as the continent rose and sank. The sedimentary strata are therefore far from being continuous sheets throughout the region, for portions of the sea bottom were at times uplifted into land, and sediments that had been recently deposited were eroded while other portions of the region were still submerged.

This submergence began at least as early as the beginning of Cambrian time, possibly as early as late Algonkian time, and in the western part of the region submergence recurred many times up to the end of the Carboniferous period. Thus several great cycles of sedimentation are recorded in the rocks of this region. The first deposits consisted of conglomerate, sandstone, and shale, laid down in early Cambrian and possibly late Algonkian time along the eastern border of the interior sea, as it encroached upon the sinking land. As the land was worn down and erosion became less active the sediments became finer, until in late Cambrian time very little suspended material reached the sea, the deposits being mainly calcareous ooze. This condition continued into the Ordovician period without a marked break in the deposition.

Accelerated erosion of the land at the end of Ordovician time culminated at the beginning of the Silurian in the deposition of a considerable thickness of quartz sand and pebbles, which formed the earliest deposits of the second cycle of sedimentation. The sediments again became finer and finer as the erosive activity on the land decreased until near the end of Silurian time, as before, only calcareous ooze was deposited.

White sand and conglomerate of early Devonian age represent another partial uplift of the land and the beginning of the next cycle of sedimentation. This was followed by a vast accumulation of fine silt and sand on the slowly sinking bottom of the shallow interior sea during Devonian time.

The advent of the Carboniferous period was marked by a resubmergence of the west side of the Highlands and the deposition of quartz sand and gravel, followed by fine silt and calcareous mud. At the beginning of the Pennsylvanian epoch there was renewed erosion on the land, which brought coarse quartz pebbles and sand into the sea. This was accompanied by a change from marine to brackish-water and marsh conditions, for with the sand and silt that were deposited were buried occasionally thick layers of carbonaceous matter representing dense growths of vegetation, which now constitute the great coal beds of the Appalachian region.

Deposition in the Appalachian Highlands practically ceased at the end of the Carboniferous period; the region was uplifted, the inland sea was drained, and the sea bottom was added permanently to the land. In the process of uplift the recently deposited sediments were highly compressed and folded. Later, during Triassic time, certain narrow basins in the Piedmont province received large quantities of distinctive red sediments brought in by floods. In the ages since that time the whole region except the portions bordering the ocean has been above the sea and has been continuously subjected to erosion, and no deposits except stream gravel, local lake sediments, and glacial drift have been left to record its history, which is, however, preserved in the present topography.

TOPOGRAPHY

RELIEF

Divisions.—The Fairfield and Gettysburg quadrangles lie in the Blue Ridge and Piedmont provinces of the Appalachian Highlands. In southern Pennsylvania and Maryland the two provinces are quite distinct, the mountains standing in sharp relief above the plateau. (See fig. 3.) The northwestern two-thirds of the Fairfield quadrangle is occupied by South Mountain, the local representative of the Blue Ridge; the rest of the area of the two quadrangles is a dissected plain, a low part of the Piedmont province, here referred to as the Gettysburg Plain. Cumberland Valley, the eastern part of the Appalachian Valley, lies just west of South Mountain.

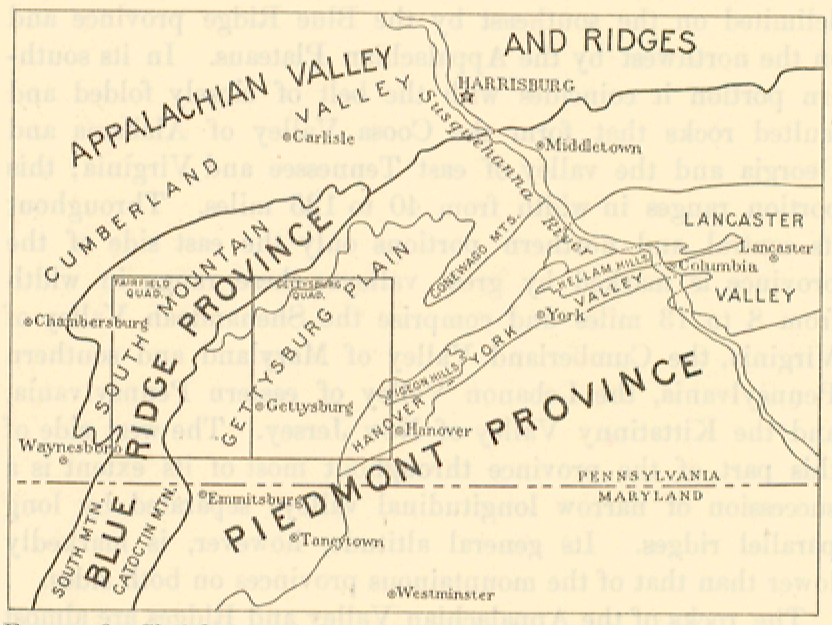

FIGURE 3.—Sketch map of the region around the Fairfield and Gettysburg quadrangles showing physiographic provinces and their subdivisions

South Mountain.—In the Fairfield quadrangle South Mountain is composed of a series of parallel ridges that trend northeastward, separated by somewhat discontinuous narrow valleys. A deep, narrow east-west valley, occupied in part by Carbaugh and Marsh Creeks, divides the ridges into two groups having slightly different trend, the ridges south of the valley trending N. 20° E. and those on the north N. 35° E.

The most continuous and prominent ridge in the southern part of the area is Green Ridge, a single steep-sided, level-topped, straight ridge about 10 miles long. It maintains an altitude of about 1,800 feet from Virginia Rock, at the south, to its north end, where it culminates in a peak at 1,960 feet. To the east of this ridge are several discontinuous ridges which have the same trend and whose general altitude is only about 1,400 feet. They are cut by deep lateral valleys which drain eastward and have steep, rugged, picturesque wooded slopes. The southernmost of these ridges, Jacks Mountain, has a more easterly trend and is more massive and higher than the others, its crest rising to 1,600 feet. There are no foothills in this part of the quadrangle, the mountain front rising abruptly 800 to 1,000 feet from the low plain at its base.

The highest mountain of this part of the area, which has a maximum altitude of nearly 2,100 feet, lies west of Green Ridge. It comprises the relatively flat-topped mountain mass which extends from Buzzard Peak to Snowy Mountain, and does not possess the longitudinal character of the other ridges in the area. To the north of this mass is a lower rather level tract only 1,700 to 1,800 feet in altitude, cut by valleys at the north into a number of discontinuous mountains. It is bounded on the west by Rocky Mountain, a sharp-crested narrow higher ridge with a northeast trend.

North of the east-west Carbaugh-Marsh Creek valley South Mountain is composed of three main parallel ridges. The general mass including Big Pine Flat Ridge, Big Flat Ridge, and East Big Flat Ridge is a broad plateau-like tract cut by gentle valleys, the heads of deeper valleys that trench the steep sides of the mountain. It rises abruptly out of the valley of Conococheague Creek in the northwest corner of the area. Its general altitude is 2,000 feet, and it culminates at the north end of Big Pine Flat Ridge at 2,100 feet, the highest point of South Mountain in Pennsylvania. Its western slope is deeply trenched by numerous lateral valleys that open out upon the limestone plain of Cumberland Valley. East of East Big Flat Ridge is a deep longitudinal valley, occupied by the headwaters of Conococheague Creek and Mountain Creek. Lateral branches from these streams cut deeply into the east slope of the mountain and form some of the rockiest and wildest ravines in the area.

Piney Mountain is a rather straight ridge that runs from the transverse Carbaugh-Marsh Creek valley far beyond the northern edge of the area. Its altitude ranges between 1,700 and 1,900 feet. It is not a rugged precipitous ridge but has a rather rounded cross section, and no deep ravines trench its sides. The valley to the east, Buchanan Valley, is a relatively wide and open intermontane valley drained by the headwaters of Conewago Creek, which passes through the Big Hill-Bear Mountain ridge to the east in a deep, sharp cleft or canyon, the steepness and angularity of which are unique in this region. Big Hill, south of the gap, is broad and massive and about 1,600 feet high. (See pls. 13 and 14.) Bear Mountain, north of the gap, is not so massive nor so regular and at the north edge of the area is broken into low knobs by lateral drainage. Foothills 1,000 to 1,200 feet high border the Big Hill-Bear Mountain ridge on the east and form a step from the mountains to the valley.

Gettysburg Plain.—The lowland stretching southeastward from the foot of South Mountain across the two quadrangles is here termed the Gettysburg Plain. It is included within the Piedmont province, but most of its surface is lower than the general level of the plateau because of the soft, easily eroded rocks that underlie it. It is part of a long, narrow low tract which is about 20 miles wide in this area. Its general height in the Fairfield and Gettysburg quadrangles is 600 feet. Around Bonneauville, southeast of Gettysburg, it forms a broad level tract at 580 to 620 feet. Into this plain the streams have cut open valleys 100 to 150 feet deep, and above it rise scattered hills to altitudes of 900 to 1,100 feet. Many of these hills are foothills of South Mountain. A hilly tract extends from McKee Knob, at the south edge of the Fairfield quadrangle, to Orrtanna, and includes the sharp tops of McKee Knob, 1,160 feet in altitude; McGinley Hill, 920 feet; Sugarloaf, 840 feet; and Wilson Hill, 980 feet. North of the Chambersburg pike are other groups of hills, of which the larger are the hill near Rocky Grove School, 960 feet; Yellow Hill, 1,400 feet; Wolfpit Hill, 960 feet; and Chestnut Hill, 985 feet. Several hills farther out in the valley, although much lower, are conspicuous because they rise abruptly out of the surrounding lowland. (See pl. 12.) They include Round Top (south of Gettysburg), 785 feet; Granite Hill, 726 feet; and Round Hill, 843 feet.

The schist hills that appear in the southeast corner of the Gettysburg quadrangle form the eastern margin of the Gettysburg Plain. The general altitude of the hilltops outside the area is 900 feet, and this upland surface is part of the Piedmont Plateau proper. The Pigeon Hills, at the eastern border of the Gettysburg quadrangle, which lie within the general area of the Gettysburg Plain and Hanover-York Valley, are over 1,000 feet in altitude and stand distinctly above the plain.

DRAINAGE

The area is crossed by the watershed between two main drainage lines, about one-half of it draining north into Susquehanna River and the other half south into the Potomac, as shown in Figure 2. In the mountains the streams flow mostly in narrow valleys with steep gradient, and the flow is generally swift. In the lowland the gradients are much reduced, the valleys are wider and flat bottomed, and many have wide flood plains that are cultivated. The streams that head in the mountains are generally bordered here and there by terraces covered with sand, gravel, and cobbles derived from the hard rocks of the mountains. The streams were formerly dammed at many places, and considerable water power was thus developed and utilized in local grist and saw mills.

Susquehanna drainage. — The drainage into Susquehanna River goes chiefly through Conewago Creek, which heads in Buchanan Valley, in the Fairfield quadrangle, passes out of South Mountain through the cleft in the Big Hill-Bear Mountain ridge, and then takes a winding course eastward across the area. A main tributary of Conewago Creek, South Branch, heads in the slate hills just beyond the south border of the Gettysburg quadrangle and drains the southeast corner of the quadrangle, joining the main stream north of New Oxford. Other tributaries from the south are relatively short and drain only small areas.

The chief northern tributary of the Conewago in this area is Opossum Creek, which heads in the valley west of Bear Mountain, passes out of the mountains through a low gap near the north edge of the Fairfield quadrangle, and joins the main stream in the Gettysburg quadrangle south of Center Mills. Bermudian Creek and Mud Run, which drain most of the northern part of the Gettysburg quadrangle, join the Conewago some miles east of the quadrangle.

Mountain Creek, which heads in a deep, narrow valley in the mountains at the north edge of the Fairfield quadrangle, is a main tributary of Yellow Breeches Creek, which joins Susquehanna River below Harrisburg. The northwest slope of South Mountain in the extreme northwest corner of the Fairfield quadrangle is drained by numerous small streams that flow into Conodoguinet Creek, also a tributary of Susquehanna River, which it joins opposite Harrisburg.

Potomac drainage.—The drainage into Potomac River follows Conococheague Creek and tributaries of Antietam and Monocacy Creeks. Conococheague Creek heads in the valley west of Piney Mountain, and its long branching tributaries drain most of the mountain area in the northwest corner of the Fairfield quadrangle.

The East Branch of Little Antietam Creek heads in the narrow valley west of Green Ridge and drains only a small area. In the southwest corner of the Fairfield quadrangle its valley widens out into a cove, which is an arm of Cumberland Valley west of the mountains.

Toms, Middle, Marsh, Rock, and Alloway Creeks, main tributaries of the Monocacy, drain the southern part of the quadrangles. Marsh Creek drains the largest area. It heads in a deep hollow on the west side of Green Ridge, passes east through the gap between Green Ridge and Big Hill, and then flows across the lowland to the southeast corner of the Fairfield quadrangle. Little Marsh Creek, a large branch that heads in deep hollows on the east side of Green Ridge, joins the main stream below Knoxlyn. Muskrat Run heads on the east slope of Big Hill not far from Conewago Creek and joins Marsh Creek south of Mummasburg. The other branches of Marsh Creek are small.

Middle Creek, which heads in a deep hollow on the east slope of Green Ridge near Mount Hope, and Toms Creek, which heads in a similar deep mountain valley west of Maria Furnace, drain all the area of mountain and plain between Green Ridge and Marsh Creek. These two streams unite a few miles south of the area before their waters join the Monocacy.

Rock Creek heads in the Gettysburg Plain close to Conewago Creek, flows south past Gettysburg, and drains the south-central part of the area. Its several long branches reach far eastward, so that but little of the area remains to be drained by Alloway Creek, which heads in the Gettysburg Plain south of Whitehall and flows south.

CULTURE

The main roads of travel in the area converge toward Gettysburg and bring tourists from all parts of the country to this center of historic events. The area is crossed from west to east by the Chambersburg pike, which is part of the historic Pittsburgh-Baltimore pike and is now included in the Lincoln Highway. It crosses South Mountain by the low pass between the headwaters of Carbaugh and Marsh Creeks, at an altitude of about 1,400 feet. Before the days of the railroad in this section of the country much of the produce of the western part of the State was hauled to market over this road, and many of the old hostelries along it are still preserved. This route was followed by the larger part of the Confederate army in its advance upon and retreat from Gettysburg. The road is now one of the most popular automobile highways of the State, leading to the many cities and resorts along its course, particularly the national reservation at the Gettysburg battlefield with its beautiful roads and commemorative monuments.

The Hagerstown road is another of the popular through lines of travel which crosses the mountains. It takes a southwest course from Gettysburg through Fairfield to Miney Valley just south of the quadrangle and then turns westward, crossing South Mountain by way of the pass at Monterey, 1,600 feet above sea level. This route was followed by part of the Confederate army in its retreat from Gettysburg. The only road that crosses South Mountain between this road and the Chambersburg pike is a little-used road that enters the mountains at Marshall, crosses the steep rocky slopes of Green Ridge at 1,750 feet, and thence passes the South Mountain Sanatorium to Montalto.

Another route across the mountains is the Shippensburg road, which runs northwest from Gettysburg through Mummasburg and Arendtsville and then through the deep gorge of Conewago Creek in the Big Hill-Bear Mountain ridge. Thence it crosses the highest part of the mountains, more than 2,000 feet above sea level, and descends to the Cumberland Valley by way of a long deep valley.

The Carlisle road runs due north from Gettysburg and enters the mountains at Bendersville. It passes over a low divide among gentle hills into valleys tributary to Mountain Creek, which it follows through the higher mountains on the north. The Harrisburg pike takes a straight north-northeast course from Gettysburg across the low hills of the Gettysburg Plain and avoids South Mountain by passing around its east end at Dillsburg, some distance north of this area.

The York pike from Gettysburg passes through New Oxford in an east-northeasterly direction. The Hanover road runs east-southeast from Gettysburg through Bonneauville and McSherrystown. The Baltimore pike has a more southerly direction and passes through Germantown and Littlestown, just south of the area. The Taneytown road runs due south from Gettysburg and the Emmitsburg road south-southwest across the gentle hills of the Gettysburg Plain.

Three lines of railroad enter this area. A branch of the Western Maryland Railway leading from Highfield, on the main line, crosses the two quadrangles from a point near the southwest corner through Gettysburg to the eastern edge at Midway, a suburb of Hanover. The local freight traffic has been greatly augmented by the diversion over this branch of much of the through freight of the Western Maryland and some from the Baltimore & Ohio Railroad. The Gettysburg & Harrisburg Railway of the Reading System, connects with the Cumberland Valley Railroad at Carlisle and terminates at Gettysburg. The chief purpose of the construction of these two roads was to make the famous Gettysburg battlefield accessible to visitors. The Frederick branch of the Pennsylvania Railroad crosses the southeast corner of the area and passes through Hanover.

An electric railroad from Hanover to Littlestown crosses the southeast corner of the area and is much used for hauling local freight and produce to market at Hanover. Another electric railroad from Chambersburg has its present terminus at the pleasure resort Caledonia Park, near the western border of the Fairfield quadrangle.

Bus lines are being established from Washington, Baltimore, Frederick, Chambersburg, York, and other cities to Gettysburg.

Farming is the chief industry in the area. Nearly the whole of the Gettysburg plain in these quadrangles is cultivated, although much of the soil is not of first quality. Only a small tract at the foot of South Mountain near Fairfield and another in the eastern part of the area around McSherrystown have fertile limestone soils.

General farming prevails and truck gardening is common near the larger towns. The gravel-covered hill country along the foot of the mountains north of the Chambersburg pike is noted as one of the best apple and other fruit sections of the State. The soil is light, aerated, and well drained, and the land is high, so that the orchards are not subject to unseasonable frost and in winter are protected by the mountains from cold northwest winds.

There are a few manufactories in Gettysburg and in some of the other larger towns, especially in McSherrystown and Midway, which are suburbs of Hanover, a large industrial center. There are several mineral industries, one of which, the manufacture of granulated greenstone, is largely restricted to this and immediately adjacent areas. There are no large mines, quarries, or pits that employ many men in the area. The few small ones that are working are described under the heading "Economic geology."

The mountain area is in large part forested. Many of the intermontane valleys have been cleared and were for a time cultivated, but these have been largely converted into pasture land or have reverted to forest. The soil of the quartzite and rhyolite areas of the mountains is light and poor and suitable only for forest. The soil of the basaltic rocks is very fertile but in most places is thin and rocky and washes badly on the steep slopes. The more level portions east of Green Ridge are cultivated and make good farm land.

Although the mountain area is primarily a wooded region and should furnish an extensive timber industry, almost no lumber is being taken out. The original forest was partly evergreen—white and yellow pine, hemlock, and fir—and partly hardwood. Most of the timber has been cut off, and the land has been burned over many times by forest fires and now is slowly being restocked with a new growth of the worthless jack pine, soft woods, and some hardwood. Recently large portions of the mountains have been made a State forest and are being restocked with white pine and other commercially valuable trees, but it will be many years before the newly planted trees grow to marketable size. (See pl. 18.) Small parts of the State forest which formerly belonged to the Mont Alto Iron Furnace Co. still retain some of the original evergreen timber; the best-known example is the beautiful grove of ancient hemlock and white pine in the gorge at Montalto Park, just beyond the west edge of the Fairfield quadrangle, where the State Forest School is located. The evergreen forests in the vicinity of the South Mountain Sanatorium largely determined the location of the State tuberculosis hospital at that place.

Owing to the frequent fires before the State forest was established there is no large growth of commercial timber, but ties, locust posts, and other small lumber are taken out in a few places. Small wood lots along the streams and on farms in the Gettysburg Plain are more carefully protected and furnish a little lumber. The wooded diabase hills in this part of the area have largely a young growth of hardwood, chiefly oak since the chestnut has been killed by the blight, interspersed with maple, birch, smaller trees, and bushes. Cedar and locust posts for farm fences are grown in many of the fields as well as in the woods.

CLIMATE

The climate of this part of Pennsylvania is ideal for agricultural pursuits. The mean annual temperature is 52°. Although the recorded highest temperature is 107° and the coldest —17°, the average number of days a year when the temperature is over 90° is only 21. The average temperature for spring is 47°; summer, 70°; autumn, 51°; winter, 28°. The summer temperature is somewhat higher in the lowland than on the mountains, where the night are always cool. In the mountains the winter season is cold and long and is destructive to fruit except in sheltered places and on the lower slopes. The average number of days in the lowland when the lowest temperature is below freezing is 110.

The average annual rainfall is 42 inches, about equally distributed between the four seasons. Severe wind storms and tornadoes are exceptional, as the mountains of the western part of the State protect the area from storms coming from the west, and those that come from the Gulf of Mexico lose much of their force before reaching this latitude. Thunderstorms accompanied by hail are sometimes locally destructive to crops in midsummer.

HUMAN HISTORY

The area as a whole was not settled by the earliest colonists, for they sought the richer soils of the limestone valleys. The streams and mountain valleys probably first attracted the trapper and hunter, but it was not long before the more fertile areas around Hanover and Fairfield were occupied by settlers. Some of Penn's colony settled in the vicinity of York Springs, just north of this area, and an old historic church and graveyard of that generation still stand on a hilltop in the northern part of the Gettysburg quadrangle.

The trail from Philadelphia and Baltimore to Fort Duquesne at Pittsburgh went through this area, because of the low divide in the mountains. Over this road were hauled the supplies for the fort and the settlers on the frontier, and the furs and other frontier products were sent back by the same route. From the earliest days this was a highway to the interior, and log huts along its course were succeeded by more permanent structures to house the traveler during the night, so that a chain of hostelries grew up, some of which still remain as landmarks.

The region, however, became historic and world renowned during the Civil War, for here was fought one of the most decisive battles of the war. Late in June, 1863, the Confederate army crossed the Potomac west of the Blue Ridge, invaded Pennsylvania, and was sweeping eastward north of Washington. The Union troops were east of the Blue Ridge and awaited the Confederates after they had come through the low pass in the mountains west of Gettysburg. The open plain

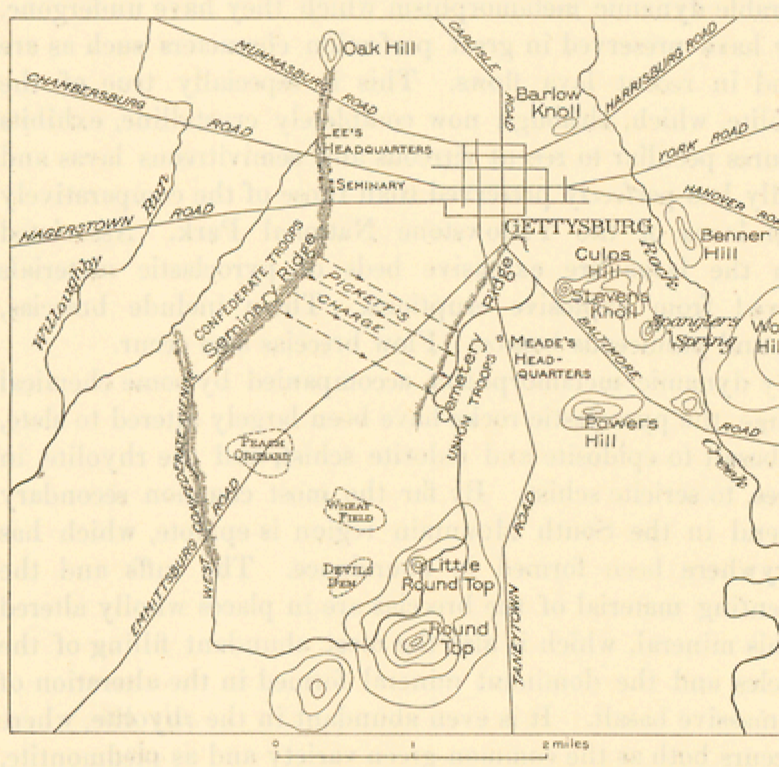

FIGURE 4.—Sketch map of the Gettysburg battlefield showing the diabase ridge occupied by the Union and Confederate troops during the battle and the higher diabase hills occupied by artillery

From map by Gettysburg National Military Park Commission, 1916

around Gettysburg was regarded as a desirable battlefield, and the troops of both armies were concentrated on opposite sides of the town. (See fig. 4.) The Confederates occupied Seminary Ridge and the low ridge to the south now followed by West Confederate Avenue, both of which are formed by diabase dikes. The surface was covered with "ironstone" boulders that had weathered from the diabase and had been piled into fences along property lines, and these fences made excellent barricades for infantry and artillery. (See pl. 8.) The Union troops occupied a similar elevated tract to the east, which is followed by the road from Cemetery Hill to Little Round Top. (See pl. 12.) This ridge is likewise composed of diabase, and here also fences made of the diabase boulders were used as barricades. The battle raged for three days between these lines, supported by artillery fire from higher diabase hills near by, and culminated in the noted Pickett's charge of Confederate soldiers, which was repulsed with terrific slaughter. The Confederates retreated southwestward through the mountains toward the ford across Potomac River at Williamsport, Md., most of them following the Hagerstown road through Fairfield and the low divide at Monterey, but the wounded and their guard followed the more convenient Chambersburg road. This historic battlefield has been made a reservation by the United States Government, which has built excellent roads throughout the area.

DESCRIPTIVE GEOLOGY

STRATIGRAPHY

The rocks exposed in the Fairfield and Gettysburg quadrangles include both sedimentary and igneous rocks. The sedimentary rocks comprise quartzites and slates of Cambrian age in South Mountain, the Pigeon Hills, and the slate hills south of Hanover, limestones of Cambrian and Ordovician age in some of the mountain valleys and parts of the Gettysburg Plain, and soft sandstones and shales of Triassic age in the Gettysburg Plain. The igneous rocks comprise volcanic rocks of Algonkian age, exposed in South Mountain and the Pigeon Hills, and much younger intrusive rock, which penetrates chiefly the Triassic strata of the Gettysburg Plain. There are also a few small remnants of basaltic lava in the Triassic sedimentary rocks. Alluvium-covered flood plains border most of the larger streams, and fluviatile gravel covers remnants of terraces along their courses. Alluvial fans composed of coarse gravel make low hills at the mouths of mountain gulches, and wash from the steep interstream slopes of the mountains covers the bedrock along most of the mountain front. The sequence, thickness, and composition of the bedded formations are graphically and concisely expressed in the columnar section.

ALGONKIAN VOLCANIC ROCKS

GENERAL CHARACTER[2]

The oldest rocks exposed in the area are a series of altered volcanic rocks, found chiefly in South Mountain and also in the Pigeon Hills. They formed the floor on which the Cambrian quartzites were laid down, and basal Cambrian conglomerate, composed chiefly of fragments of the volcanic rocks, rests unconformably on their beveled upturned edges. The pre-Cambrian rocks crop out in the intermontane valleys and on the lower ridges of South Mountain; the higher peaks and ridges are capped by the harder Cambrian quartzites. About two-thirds of the mountain area of the Fairfield quadrangle is composed of the volcanic rocks.

These volcanic rocks comprise lavas and pyroclastic sediments. The lavas are of two sharply contrasted types—rhyolitic lavas, now aporhyolite, and basaltic lavas, now metabasalt. No rocks of intermediate type have been found. The lavas are remarkable because, in spite of their great age and the considerable dynamic metamorphism which they have undergone, they have preserved in great perfection characters such as are found in recent lava flows. This is especially true of the rhyolite, which, although now completely crystalline, exhibits textures peculiar to recent vitreous and semivitreous lavas and hardly less perfectly preserved than those of the comparatively fresh lavas of the Yellowstone National Park. Associated with the lavas are extensive beds of pyroclastic materials derived from explosive eruptions. These include breccias, tuff, and pumiceous bombs. Flow breccias also occur.

By dynamic metamorphism, accompanied by some chemical change, the pyroclastic rocks have been largely altered to slate, the basalt to epidosite and chlorite schist, and the rhyolite, in places, to sericite schist. By far the most common secondary mineral in the South Mountain region is epidote, which has everywhere been formed in abundance. The tuffs and the cementing material of the breccias are in places wholly altered to this mineral, which is also the most abundant filling of the vesicles and the dominant mineral formed in the alteration of the massive basalt. It is even abundant in the rhyolite, where it occurs both as the common green variety and as piedmontite, the dark-red manganese epidote.

RELATIVE AGE

The relative age of the rhyolitic and basaltic rocks can not be positively determined from the evidence now at hand, the relations in the few exposures where the two sorts of rock are in contact not being decisive. Where the basalt seems to overlie the rhyolite it is not certain that the two lavas have not been overturned or that the rhyolite may not be an intrusive rock which invades the basalt. Where the rhyolite overlies the basalt and both rocks are undoubtedly effusive, as in a cut in the old National (Bingham) copper mine, the contact may be a fault plane, represented by a thin layer of sericite schist between the two rocks.

In the Mercersburg-Chambersburg folio of the Geologic Atlas the view was expressed that the basalt is probably older than the rhyolite and was covered by it and that only small areas of the basalt have been uncovered by erosion. This view was based on the fact that in Pennsylvania the basalt is less widely exposed than the rhyolite and, if it is younger than and once covered that rock, most of it must have been removed by erosion, so that the overlying Cambrian conglomerate should consist largely of basaltic detritus, whereas this conglomerate contains but little such material and is made up chiefly of rhyolite fragments.

In Maryland and Virginia, however, the basaltic rocks are more widely exposed than the rhyolitic rocks and were regarded by Keith[3] as the younger. That they are probably younger rather than older than the rhyolite is also suggested by the fact that in many places in Pennsylvania the rhyolite nearest the basalt is red, presumably due to the increased oxidation of the iron in the rhyolite by the heat of the basalt. This is well shown at Gum Spring, a mile north of Gladhill, where rounded fragments of brick-red rhyolite porphyry are included in the basalt. Similarly the rhyolite near the dikelike bodies of basalt along the east slope of the mountain northwest of Fairfield is harder than elsewhere and makes ridges and lines of knobs, and the rock is brittle and breaks into angular blocks instead of into hackly schistose fragments such as are elsewhere characteristic of the rhyolite. This hardening is apparently due to baking by the basalt at the contact.

Furthermore, the core of the Big Hill-Bear Mountain and Snaggy Ridge anticlines is composed chiefly of rhyolite with basalt on its flanks and is believed to represent an eroded pre-Cambrian anticline from the crest of which the younger basalt was removed. The basalt on the flanks, especially southeast of Green Ridge, occurs in numerous narrow bands, which appear to represent thin flows of basalt that alternated with rhyolite lava flows toward the end of the rhyolitic eruption. The basalt bands are more numerous and larger toward the south, and in Maryland they predominate over the rhyolite, indicating that the source of the basalt was in that locality.

The general conclusion from these facts is that in the South Mountain region the rhyolite was erupted first, that near the end of the rhyolitic period thin basaltic flows alternated with the rhyolite, and that eventually, at least in Maryland, basalt flows predominated.

APORHYOLITE

Distribution.—The rhyolitic volcanic rocks occupy a belt having an average breadth of 5 miles and a maximum breadth of 8 miles, which crosses the Fairfield quadrangle from the southwest to the northeast corner. They are overlain by Cambrian sandstone, which forms the crests of Snowy Mountain, Rocky Mountain, and Piney Mountain. The lavas of Big Hill and Bear Mountain are compact, fine grained, and dense; near the Chambersburg pike they are offset by an east-west fault, beyond which they continue southward in Mount Newman and Snaggy Ridge. Amygdaloidal facies are found in the southern part of the belt west of Snaggy Ridge and at the Bingham copper mine, north of Pine Mountain, and the pyroclastic rocks and associated sericite schists are most abundant in Buchanan Valley and in the extreme northeast corner of the Fairfield quadrangle but occur also at the mouth of Copper Run.

Character.—Most of the lava is a hackly-fractured, hard, dense, fine-grained purplish felsitic rhyolite, in part containing porphyritic crystals of feldspar. The rock has a greater variety of colors than the metabasalt and is easily distinguished from it in the field. The prevailing color is bluish purple or blue-gray, which weathers to whitish gray, but rich purple, pink, brick-red, buff, and light green are also characteristic colors. The brick-red color seems to be most pronounced near bodies of basalt and may be due to alteration of iron oxide by the heat from the basalt. The green schists owe their color to abundant sericite, the mottled red and green sericitic schist to hematite and hydrous iron oxide, and the red and blue schists to iron oxide.

The original constituents and texture of the lavas show that they belong to the rhyolite family, but on account of the alteration and devitrification that they have undergone they are called aporhyolite.

Phenocrysts are inconspicuous as a rule, but prominent opaque white phenocrysts are striking features of some of the brick-red lavas, and pink or white phenocrysts occur in some of the blue lavas. (See pl. 32.) Layers composed of spherulites ranging in size from that of a pea to that of a hickory nut and lavas with delicate straight or wavy flow banding are common. (See pls. 25–29, 34.) Lithophysae, though rarely preserved in perfection, are also conspicuous in these lavas, but amygdaloidal varieties are less common than in the metabasalt. In a few localities, chiefly toward the south, amygdules are conspicuous. At the National (Bingham) copper mine there is a remarkably handsome rock containing almond-shaped amygdules of limpid quartz with concentric layers, stained bright green by copper carbonate, set in a pale-pink or drab matrix. (See pl. 33.) The great mass of lava that forms Bear Mountain, Big Hill, Mount Newman, and Snaggy Ridge and is thought to be the oldest rock in the region is nonamygdaloidal.

The lavas are brittle, the massive varieties breaking with a conchoidal fracture and knifelike edges and the closely jointed varieties splitting readily into rectangular blocks. In places the rock is so thoroughly jointed that it crumbles into small irregular blocks at the blow of a hammer. Like the brick-red color, the hardening and jointing seem to be most pronounced near masses of the basalt and may be due to contact with hot basaltic lava.

Compression has developed a schistosity which is most marked in the compact lavas of Big Hill and Bear Mountain, where the rock breaks into great hackly slabs. (See pl. 1.) Red, blue, and silvery-green schists, green and red mottled schist, and mottled clastic schist, associated with the massive lavas, have plainly been developed from them and from the pyroclastic rocks by compression. A single hand specimen may show a gradation from massive porphyry to sericite schist, the feldspar of the original rock having been altered to sericite. Belts of sericite schist are found along many of the contacts of the metabasalt and aporhyolite in places where movement and shearing have evidently been concentrated, conspicuously so along the contact northeast of Pine Mountain. Sericite schists have also been developed from tuffs by compression, as in Buchanan Valley. Sericite schists, of whatever origin, are indicated by the same color pattern on the maps.

Flow breccia.—Flow breccias are rare and have not been separately mapped. They are made up of angular fragments which were borne in a viscous magma, as is shown by their arrangement in flow lines and by the way in which aggregates of fragments fit one another. The fragments range in size from microscopic dimensions to several inches across. The matrix is of the same nature as the groundmass of the nonfragmental lava. These breccias were presumably formed through the breaking up of already cooled portions of the lava by further movement of the viscous mass. They are found half a mile northeast of Maria Furnace, 1 mile northwest of Pine Mountain, and 2 miles east of the South Mountain Sanatorium. The rock at the last-named place is a compact breccia of sharply defined angular fragments that takes a good polish and makes a handsome ornamental stone. (See pl. 31.) Its occurrence is shown on the economic-geology map.

Tuff breccia.—The tuff breccia is made up of bluish-purple to red angular fragments, ranging in diameter from microscopic dimensions to 5 centimeters or more, in a red or purple matrix which is siliceous and commonly very ferruginous and is presumably a fine tuff. (See pl. 35.) These breccias have for the most part been changed to slate, whose mottled surfaces proclaim its clastic origin. They are most abundant a mile northwest of Brady School, and occur throughout this belt in Buchanan Valley and in a small area in the valley of Raccoon Creek.

Tuffs.—The tuffs, containing only fine pyroclastic sediment, are not mottled, and some that are hard and even grained are natural whetstone. The known distribution of the whetstone is shown on the economic-geology map. Tuffs occur with the breccia a mile northwest of Brady School. Some have been changed to sericite schist and are not distinguished from other sericite schist on the map.

Microscopic character.—Quartz and feldspar are the dominant and usually the only essential constituents present in the aporhyolite. The only ferromagnesian constituent, biotite, is neither abundant nor widespread in its occurrence; most of the lava is free from this mineral. Of the accessory constituents, magnetite and ilmenite, the former is the more plentiful. Secondary constituents are hematite, leucoxene, kaolin, sericite, quartz, epidote, and chlorite.

Both quartz and feldspar occur in two generations. Quartz, less abundant than feldspar in the first generation, occurs in bipyramidal or rounded, embayed phenocrysts. The quartz of the groundmass, exclusive of the secondary quartz, occurs characteristically as a component of a granular quartz-feldspar mosaic so fine grained that it is not possible to separate the two minerals. Feldspar phenocrysts are abundant, though small and commonly inconspicuous in the hand specimens. The feldspar is alkaline and usually occurs in the form of perthitic intergrowths of orthoclase and albite.

Epidotization has not occurred in the rhyolitic lavas to the same degree as in the basaltic, but epidote is still a prevailing alteration product and cementing material; where epidote fills seams and vesicles of a bluish-purple rhyolite, it has robbed the magnetite in the lava of ferrous oxide, producing a pink hematitic zone reaching in some places a width of 1.5 centimeters and sharply contrasting with the otherwise prevailing blue color. Where epidote is the cementing material of a breccia, the larger fragments show a similar pink hematitic zone, and the smaller fragments are completely changed to the pink rock.

Two accessory minerals of considerable rarity, piedmontite and scheelite, are found in the aporhyolite lavas. The purple and pink aporhyolites are especially rich in the manganese epidote, piedmontite. This mineral is found in radiating aggregates filling cavities and seams in brecciated lava and also as a microscopic constituent secondary to the feldspar phenocrysts, where it is usually associated with epidote, the deep carmine of the piedmontite grading through the faintest rose color to the pistachio-green of epidote.

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[2] A detailed petrographic description of these volcanic rocks is given by F. Bascom in U. S. Geol. Survey Bull. 136, 1896.

[3] Keith, Arthur, The geologic structure of the Blue Ridge in Maryland and Virginia: American Geologist, vol. 10, p. 367, 1892.

The best specimens of piedmontite are found in the aporhyolite area on the southwest flank of Pine Mountain half a mile northwest of Gladhill and near Boyd School, on the east side of Piney Mountain. Piedmontite has also been found in microscopic quantities in other parts of the Fairfield quadrangle, especially in Buchanan Valley, 2 miles north of the Chambers. burg pike, and in the breccias 1 mile northwest of Brady School. Here it is associated with scheelite.

The petrographic interest of aporhyolite centers about the fabric of its groundmass. The fabric rather than the constituents reveals the origin and conditions of solidification of the lava. A finely granular quartz-feldspar mosaic is a prevailing fabric, with which other fabrics are associated. For the most part the crystallization of this mosaic is believed to have been secondary to solidification, because of the fabrics with which the mosaic is associated and which it locally appears to replace or still more commonly to obscure. Of almost equal prevalence with this granular fabric is the micropoikilitic fabric, in which relatively large anhedra of quartz act as a matrix for numerous lath-shaped microliths of feldspar, scattered uniformly through the quartz and independently oriented. This fabric gives a mottled or patchy appearance to the groundmass. Where this fabric is combined with porphyritic texture, the inclosing quartz anhedra act as secondary enlargements of the quartz phenocrysts and inclose abundant small feldspar crystals. In the aporhyolite of South Mountain the micropoikilitic fabric and the associated granular fabric are found replacing fabrics known to be primary and so are believed to be secondary to the solidification of the lava. In the metabasalt, where the micropoikilitic fabric has been found replacing the ophitic fabric, it is obviously secondary.

The fluidal fabric, which is so marked a feature of the hand specimen, is found to be due to the arrangement of trichites of magnetite and hematite in sinuous interrupted planes, bending around the phenocrysts. (See pls. 28, 29.) The amygdules and the stringers, shreds, and curved patches of color take part in and emphasize this fabric. By means of this fabric there may be formed a more or less complex network of interlacing bands, and in some of the rock dark lines outline oval and spherical spaces which contain phenocrysts in or near their centers, and the crystallization is regarded as having once been spherulitic.

Spherulitic crystallization manifests itself in one of three ways—(1) in the formation of spherulites of considerable size, spherical or spheroidal in shape; (2) in a microspherulitic fabric, where minute spherulites are in close juxtaposition and therefore polygonal in form; (3) in chain spherulites, where minute spherulites have developed in roughly parallel planes, giving in cross section the appearance of beads on a chain. (See pls. 25–27.)

The irregularly distributed detached spherulites, embedded in a groundmass, are larger than the other forms produced by spherulitic crystallization, even the smallest being discernible with the naked eye. Although they possess a clear-cut, conspicuous outline in ordinary light, many of them completely disappear between crossed nicols, owing to the replacement of the original radiating crystallization by either granular or micropoikilitic fabric. Many of the spherulites are highly colored with hematite or with hematite and magnetite combined, distributed in twofold or threefold concentric zones alternating with zones that are relatively free from the iron oxides. Some of the smaller spherulites have altered into a single large quartz crystal inclosing small feldspar crystals, a change which can be detected only in polarized light. In the chain spherulites the radial growth is completely replaced by a fine quartz mosaic, and the only clue to the original character of the crystallization is found in the curved outlines.

The lithophysal fabric, which has its origin in the shrinkage of a zonally crystallized spherulite and originally consisted in concentric shells separated by hollow spaces, is characteristic of some of the lavas of the area drained by Raccoon Creek and is best revealed in hand specimens, in which it is brought out by weathering. The shells now show a granular quartz-feldspar crystallization, and the spaces between them are filled with quartz, which in some places weathers in relief and in others shows as dark concentric zones against the light-pink groundmass.

Perlitic parting, or concentric spherical cracks, such as are produced in the contraction of a cooling glass, is preserved in considerable perfection in the aporhyolite lavas. This parting can be seen under the microscope only in ordinary light and is obscured with crossed nicols by the granular crystallization which has replaced the original glass.

The amygdaloidal texture adds much to the beauty of the lavas but possesses little of petrographic interest. All the vesicles, unlike those in metabasalt, have been elongated by flow movement and are filled with epidote (which is rarely the manganese epidote piedmontite), with quartz, or with both. Where both minerals are present epidote occupies the center.

The close resemblance of these varied fabrics of the aporhyolite to those of modern lavas is obvious; the divergence lies only in the entire absence in the aporhyolite of a glassy base. Because of the indications, which have been cited, of the original existence of such a base and because of the many examples in which the granular or the poikilitic crystallization is obviously secondary to the spherulitic fabric, it is concluded that the present granular or poikilitic crystallization of the groundmass is the result of devitrification by crystallization of a vitreous or semivitreous base.

Chemical composition.—The chemical composition of the aporhyolite is shown in the following table:

Analyses of aporhyolite from the Fairfield quadrangle and vicinity

	1	2	3	4
SiO_2	77.13	76.34	76.06	75.85
Al_2O_3	10.65	11.60	11.24	11.39
Fe_2O_3	2.85	2.41	1.97	3.10
FeO	.39	.30	1.36	.40
MgO	Trace.	.06	Trace.	.14
CaO	.08	.55	.58	Trace.
Na_2O	3.29	5.50	2.80	2 73
K_2O	4.66	2.75	4.95	5.50
H_2O-	.06	.39	.37	.20
H_2O+	.13	.10	.22	
TiO_2	.22	.26	.30	.30
CO_2	.12	Trace.		.14
P_2O_5	Trace.	Trace.		.10
MnO	.33	Trace.	.20	.01
BaO		.09		
	99.91	100.35	100 05	99 86

1. Aporhyolite, 1½ miles north of Idaville, just north of the Gettysburg quadrangle. W. T. Schaller, analyst, U. S. Geol. Survey.
2. Spherulitic aporhyolite, 2 miles west of Maria Furnace, Fairfield quadrangle. H. N. Stokes, analyst, U. S. Geol. Survey.
3. Aporhyolite, 1½ miles northwest of The Knob, Green Ridge, Fairfield quadrangle. George Steiger, analyst, U. S. Geol. Survey.
4. Aporhyolite, west of Green Ridge, near head of Marsh Creek Hollow, Fairfield quadrangle. W. T. Schaller, analyst, U. S. Geol. Survey.

The analyses, which were made from the freshest material obtainable, show a uniformity of composition except in No. 2, in which Na_2O shows a great preponderance over K_2O, which is reflected by the mineralogic composition of the rhyolitic lavas. The constituents of No. 1 determined in the slide are quartz, orthoclase, perthitic intergrowths of orthoclase and albite, and titaniferous magnetite. Quartz, potassium-sodium feldspars, and titaniferous magnetite, with secondary sericite and hematite, are the minerals composing No. 2. The constituents of No. 3 are quartz, potassium-sodium feldspars, plagioclase, and titaniferous magnetite. No. 4 in addition to quartz, potassium-sodium feldspars in perthitic intergrowths, and titaniferous magnetite, contains biotite, which is represented by a few scanty pale-green blades.

METABASALT

Distribution.—The metabasalt in South Mountain occurs in narrow belts which trend northeastward and extend interruptedly from the south to the north side of the area. The wider belts, which are a mile wide in the southern part of the area, become narrower toward the northeast, where the basalt bodies have the appearance of sills or thin interbedded layers. On the east the belts are cut off by the Triassic normal fault, and on the west they are overlapped by Cambrian sandstones. Several varieties of the basaltic rocks, including massive greenstone, speckled schist, and amygdaloid, occur also in the Pigeon Hills, only the extreme west end of which extends into the Gettysburg quadrangle.

Character.—The metabasalt is prevailingly a greenstone, although some of it is purple or bluish gray. The shade of green which the rock exhibits depends on the dominant alteration product: epidote, the commonest alteration mineral, gives a light yellowish-green color, chlorite and actinolite give a darker green, and a mixture of the three gives intermediate shades. The purple and gray varieties owe their colors to iron oxide and to relative scarcity of ferromagnesian alteration products.

The rocks are either massive, schistose, or slaty; compact or amygdaloidal; porphyritic or nonporphyritic. The schistose type is the most abundant, the amygdaloidal texture is the most conspicuous, and the nonporphyritic habit is the rule.

There are two prevailing types of greenstones, which have not, however, been separately mapped, because of the difficulty of distinguishing them. They are a tough, massive to schistose bluish-gray to blue-green rock with spherical or irregular amygdules and a nonamygdaloidal or inconspicuously amygdaloidal rock. The amygdules in the rock of the first type are composed of quartz, or epidote, or both, or, in the schistose facies, of lustrous beads of chlorite. (See pl. 36.) The quartz amygdules, irregular in form and size and weathering in relief, give the rock a conspicuously rough surface and conglomeratic aspect. (See pls. 37, 38.) In the few places where the amygdules are spherical and of uniform size they closely resemble the spherulites so abundant in the rhyolitic lavas of the region. That some of the original basalt was pumiceous is shown by lavas that are now composed almost wholly of amygdules, such as the rock half a mile northeast of Mount Hope, that at the head of Hayes Run, and that at Gum Spring, a mile northeast of Gladhill.

The rock of the nonamygdaloidal type is more schistose and darker green than the amygdaloid rock and shows blades of actinolite and chlorite when examined under the microscope. The rock of either type may grade into a chlorite schist.

The original texture and composition of the rock ally it with basalt, but so great has been the alteration through dynamic metamorphism that little of the original mineral constituents remains. The rock is therefore called metabasalt. The metabasalt of these quadrangles is part of a great complex of basaltic rocks which occupies considerable areas in Virginia and Maryland and smaller areas in Pennsylvania.

The basaltic pyroclastic rocks are more abundant south of this area than within it, and the vent of the basaltic lava is believed to have been situated in that direction. The coarsest material, formerly a basaltic tuff breccia, is now a mottled slate. The mottling is due to fragments, now angular or subangular thin plates or scales of all sizes, the largest 15 millimeters across, which are of different composition from the matrix. The fragments that have been altered to light-colored sericite are conspicuous in the fine-grained, nearly aphanitic purple to dark-gray chloritic and highly ferruginous matrix. Such a slate is well exposed south of Jacks Mountain, especially along the road below the railroad station. (See pl. 39.) Similar rock was noted along the east front of Piney Mountain at the south end of Buchanan Valley, east of Newman School, and in the Pigeon Hills. In some places basaltic lava has been later shattered and recemented with epidote and quartz, and much of it is brightly colored by hematite, closely resembling tuff breccias. The purple fragments, green epidote, and white and red quartz produce a conspicuously bright patchwork effect.

The finest tuff is dense and aphanitic and now consists largely of epidote, actinolite, chlorite, quartz, and magnetite. Only one specimen of this rock was found in the quadrangles, on the slope of the northeast end of Green Ridge, three-fourths mile south of the Chambersburg pike.

Microscopic character.—The basaltic lavas exhibit great uniformity of original fabric and constituents; the constituents were feldspar, augite, olivine, and magnetite or ilmenite, and the inclosure of earlier formed feldspar in augite gives an ophitic fabric. Feldspar is the best preserved of the silicates, though it, like the others, is in places completely altered. It originally formed minute lath-shaped crystals and determined the ophitic fabric: more rarely it formed phenocrysts. Both orthoclase and plagioclase were present. The feldspar has been replaced locally by either epidote or quartz. That the dominant original ferromagnesian constituent was a pyroxene is probable, but none of it remains, actinolite, chlorite, or epidote, or any two or all three of these minerals, having replaced the pyroxene. Olivine is rare and is commonly altered to chlorite and epidote and recognized only by its form. Magnetite is still abundant, although some of it has been changed to hematite. Ilmenite is almost universally altered to white granular leucoxene.

The present character of the rock is determined by the alteration products, of which epidote is most abundant and quartz next. These two minerals filled the vesicles, cemented the cracks, and thoroughly saturated the rocks. Epidote forms both granular aggregates and large crystals, obscuring the original fabric; quartz forms large interlocking masses inclosing the magnetite and epidote. Where the rock is schistose the dominant alteration products are actinolite and chlorite, though some epidote is everywhere developed. In the most schistose facies chlorite forms the amygdules, which are almond-shaped and flattened to paper thinness. Calcite is rare, but in some places it forms the amygdules, cements cracks, and in general plays the part of a secondary mineral. Hematite is abundant as pigment and occurs more rarely as vein material. Amphibole asbestos is found in some of the quartz-cemented cracks. Native copper is found in the amygdules and in crevices, associated with azurite, malachite, chrysocolla, chalcocite, cuprite, and orange-colored hydrous copper oxide, or "hydrocuprite."

The dominant alteration product can be determined from the amygdules. Quartz amygdules are found only in the siliceous purple metabasalt, which contains also magnetite, hematite, and granular epidote, in a groundmass of quartz, preserving in outline the ophitic fabric. Epidote amygdules are associated with epidotization of the whole rock, and chlorite amygdules with the actinolite-chlorite schists.

Chemical composition.—The chemical composition of two typical specimens of metabasalt is given in the following table:

Chemical composition of metabasalt from Fairfield quadrangle

	1	2
SiO_2	50.36	46.79
TiO_2	3.10	1.66
Al_2O_3	17.37	14.22
Fe_2O_3	8.13	5.10
FeO	4.33	9.42
MnO	.24	.18
MgO	3.57	5.86
CaO	4.29	10.14
Na_2O	4.74	2.38
K_2O	.08	.77
H_2O-	.16	.54
H_2O+	2.73	2.98
CO_2	Trace.	
P_2O_5	.63	.35
	99.73	100.39

1. Metabasalt, northwest of Devils Racecourse, Gum Spring Road, Fairfield quadrangle. Analyst, W. T. Schaller, U. S. Geol. Survey.
2. Metabasalt, 2¼ miles west of triangulation station on Green Ridge, Fairfield quadrangle. Analyst, George Steiger, U. S. Geol. Survey.

The specimens chosen for analysis represent the two prevailing types of the metabasalt. No. 1 is a rather massive bluish green amygdaloid in which the feldspar laths are still fairly fresh. The plagioclase is andesine, and the other constituents are magnetite, ilmenite, chlorite, quartz, and epidote. The fabric tends toward the trachytic, and the rock is rather more andesitic than basaltic. No. 2 is a dark yellowish-green nonamygdaloidal schistose rock, containing actinolite, chlorite, epidote, ilmenite, magnetite, finely granular feldspar, and apatite. The original fabric has been obliterated by the development of actinolite. This rock is more typically basaltic.

SEDIMENTARY ROCKS

The sedimentary rocks in the Fairfield and Gettysburg quadrangles comprise sandstone, shale, and limestone which are part of the sedimentary series that is coextensive with the Appalachian Highlands from New York to Alabama, but the formations differ in detail from place to place. So far as is possible the same formations are recognized and given the same names throughout the region. Of the formations occurring in this area some have their type section in Tennessee and other parts of the South and others in New York, but the greater number have been less widely traced, and for them local names are employed. They are described in the following paragraphs according to age, the oldest first.

CAMBRIAN SYSTEM

GENERAL CHARACTER

The rocks of the Cambrian system in this and adjacent areas comprise a lower series of sandstone and quartzite with interbedded schist and slate and an overlying series of thick limestone and dolomite with some shale. Named from the base up the formations represented are the Loudoun formation, Weverton sandstone, Harpers schist with Montalto quartzite member, and Antietam sandstone in the lower series and the Tomstown dolomite, Waynesboro formation, Elbrook limestone, and Conococheague limestone in the upper series. The sandstone and schist formations have been recognized throughout the length of South Mountain from Potomac River to Dillsburg, Pa. In the Pigeon Hills and the slate hills south of the limestone valley at Hanover the quartzite at the base of the arenaceous series is called the Chickies quartzite and includes a basal conglomerate member called Hellam.

The Cambrian and Ordovician limestones of the northern Appalachian Valley are known comprehensively as the Shenandoah group. In the Cumberland Valley, in southern Pennsylvania and Maryland, the group is divisible into seven formations, named, from the bottom up, Tomstown, Waynesboro, Elbrook, Conococheague, Beekmantown, Stones River, and Chambersburg. These formations, of which the first four are Cambrian, can be generally recognized and mapped throughout the valley, especially by the aid of fossils. They have been described in detail in the Mercersburg-Chambersburg folio, which treats of the adjacent quadrangles on the west. Only the lower two formations, the Tomstown and Waynesboro, enter the Fairfield quadrangle from the Cumberland Valley. The limestone formations recognizable in the Cumberland Valley are not so clearly defined in the small limestone areas just east of South Mountain, where they are also poorly exposed. In the limestone area at Fairfield most of the rock exposed is believed to be the representative of the Ordovician Beekmantown limestone, and that name is tentatively used for these rocks, but it is recognized that some of the beds may be Conococheague or Elbrook. Four formations are recognized in the limestone area around Midway and Hanover, and their general equivalence with those in the Cumberland Valley has been established, but as they are continuous with the formations in the York-Lancaster Valley, they will be designated by the names applied there—Vintage dolomite, Kinzers formation, Ledger dolomite, and Conestoga limestone. The first three are Cambrian; the Conestoga, which unconformably overlies the others, is Ordovician.

LOUDOUN FORMATION

Character and thickness.—The oldest sedimentary formation in the area here described consists of purplish arkosic conglomerate and sandstone and fine sericitic slate. These rocks are in general soft and easily eroded and are nearly everywhere concealed by the débris of harder overlying sandstones. Where exposed they are made up of large and small fragments of underlying volcanic rocks, with vitreous quartz grains and pebbles in most layers. Nearly all the fragments of volcanic rock large enough to be identified are rhyolite or slaty rhyolite tuff. Some flat fragments of the purple slaty tuff measure more than 2 inches across. Much of the material is finely comminuted, but its purplish-red color indicates the same origin as that of the larger particles. The rocks have generally a schistose structure which dips southeastward and was produced by the compression that resulted in the folding, and because of this condition the arkose is not easily distinguishable from the softer schistose rhyolite. No fragments of metabasalt were recognized in the rock.

The formation is best exposed on the east slope of Piney Mountain. Fine-grained purplish-gray soft sericitic schist or phyllite forms its lower part. Much of the rock is blotched by fragments of similar material, which probably represent original fragments or pebbles. In an old quarry at the north edge of the Fairfield quadrangle, where the schist was once prospected for roofing slate, it is dark gray, banded with white and pink, and generally fine grained. (See pl. 4.) In another slate prospect at the head of Mountain Creek dark-gray fine-grained schist with inclusions of purple schist fragments, mottled purple and green schist, and fine schistose sandy beds containing quartz grains are also well exposed. At many places the outcrop of the lower beds is concealed by large slabby fragments of higher beds.

Near the top of the formation are harder schistose arkosic conglomerate and sandstone that break up into large slabs and cover the slope below. These slabs are conspicuous along the foot of Piney Mountain from Newman School to the north edge of the quadrangle and also along the foot of East Big Flat Ridge, adjacent to the Mountain Creek valley. The rock is colored purplish by the fragments of rhyolite and tuff it contains, but there are also numerous round quartz pebbles 1 inch and more in size.

A detailed section of the formation could not be measured because of the lack of continuous exposures. From its exposure on the east slope of Piney Mountain, where the base of the formation crops out along the foot of the ridge and the upper schistose sandstone marks the top, the estimated thickness of the formation, which has a gentle westward dip, is about 550 feet. Near the type locality in Virginia the thickness determined by Keith ranged from a feather edge to 800 feet.

Distribution and surface form.—The formation has been recognized in nearly every locality in South Mountain where the Cambrian strata rest on older rocks. Its most conspicuous outcrops are on the steep eastern slopes of Piney Mountain, East Big Flat Ridge, Rocky Mountain, Green Ridge, and the northeastern slopes of Snowy Mountain. It was not clearly distinguishable along Rocky Mountain and Snowy Mountain, in the adjacent Chambersburg quadrangle, because of poor exposures, and in the Mercersburg-Chambersburg folio its beds were therefore included with the Weverton sandstone. It also forms the lower southeast slope of Jacks Mountain and is present on Pine Mountain and in the valley west of Jacks Mountain. It is probably present but was not observed on Rock Top. In the Pigeon Hills the base of the Cambrian is not noticeably composed of soft arkosic fragments of volcanic rocks like the Loudoun but is siliceous and of gray to rusty color like the higher feldspathic sandstones. If the Loudoun formation is represented there it is included with the Hellam conglomerate member of the Chickies quartzite.

Because it is generally soft and easily eroded and is overlain by hard sandstones, the Loudoun formation occupies steep slopes of mountains capped by the harder rocks. As the sedimentary rocks in general dip toward the west the overlying harder beds almost invariably form the western or dip slopes of the ridges and the softer basal beds the steep eastern slopes.

Correlation.—The formation was named from Loudoun County, Va., where it was first studied and is excellently exposed. According to Keith[4] it is there composed of sandstone, arkosic schist, conglomerate, slate, and limestone. It has been traced along Catoctin and South Mountains in Maryland into Pennsylvania, but no limestone has been observed in it as reported in Virginia. In the Mercersburg-Chambersburg folio the poorly exposed basal arkosic material in Rocky Mountain and on the west and north slopes of Snowy Mountain was regarded as the basal beds of the Weverton and was so described and was not separated as the Loudoun formation.

Coarse sandstones at the base of the Cambrian section in the Pigeon Hills, mapped as the Hellam conglomerate member of the Chickies quartzite, probably constitute the corresponding formation in this eastern belt.

[4] Keith, Arthur, U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, pp. 333-335, 1894.

WEVERTON SANDSTONE

Character and thickness.—Overlying the Loudoun formation throughout South Mountain is a series of gray and purplish feldspathic sandstones, quartzites, and conglomerates called the Weverton sandstone. Good sections of the formation are nowhere exposed in the area, and it is even difficult to construct an approximate section showing the sequence of beds. The best place to determine this sequence and estimate the thickness of the formation is at the south end of Rocky Mountain, in the Chambersburg quadrangle, where the beds stand nearly vertical and are fairly well exposed in the sharp gorge called The Narrows. Another place where the formation is well exposed is at The Cascades, on Falls Creek, just south of the Fairfield quadrangle. Here the strata are vertical and comprise thick beds of coarse gray quartzite at the base, dark-gray to purplish conglomerate with white to pink quartz pebbles above, and massive coarse dark-gray quartzite at the top.

The base of the formation is a hard massive quartzitic conglomerate, generally purplish or reddish but in places gray, which forms the crest of most of the higher mountains in the area and the backbone of Rocky Mountain. It is composed of small fragments of purplish rhyolitic lava and grains of quartz and contains scattered large round pebbles of vitreous white quartz. It is in general firmly cemented into a resistant quartzite whose rocky ledges form the crests of the mountains and whose hard, resistant fragments cover the eastern slopes and conceal the underlying softer Loudoun formation. In places its outcrops on the mountain tops form prominent rocky crags, such as Virginia Rock and Wildcat Rocks, on Green Ridge; Chimney Rocks and Monument Rock, on the south end of Snowy Mountain; and Bare Rock, on Monterey Peak, just south of the quadrangle, clearly visible from the Claremont Hotel at Charmian. (See pls. 2, 3.) At The Cascades, where Falls Creek tumbles over these rocks just south of the quadrangle, there is a popular scenic spot conveniently reached by patrons of both the Western Maryland Railway and the Waynesboro-Pen Mar electric road. The strata there are vertical and comprise thick beds of coarse gray quartzite at the base, dark-gray to purplish conglomerate with white to pink quartz pebbles above, and massive coarse dark-gray quartzite at the top.

Above the basal conglomerate are thinner-bedded sandstones and some poorly exposed, probably shaly beds, succeeded by harder gray feldspathic quartzite and some hard white quartzite. (See pl. 15.) These upper hard beds form the west side of most of the massive Weverton sandstone ridges, but in some places they make a separate ridge, as in the south end of Green Ridge, where the western spur is composed of this upper layer. Likewise in the south end of Snowy Mountain the beds dip so gently that the upper quartzite makes a distinct ridge, Briar Mountain, separated by a deep ravine from Buzzard Peak, which is composed of the lower conglomerate.

The approximate thickness of the formation as determined by its dip and width of outcrop at several places in the Fairfield quadrangle is 750 feet.

Distribution and surface form.—The Weverton sandstone forms most of the higher ridges in the Fairfield quadrangle, chief of which are Piney Mountain, Big Flat Ridge, Rocky Mountain, Snowy Mountain, and Green Ridge. It also forms Wildcat Hill, the upper slopes of East Big Flat Ridge, the small isolated Pine Mountain and Rock Top, and the higher parts of Jacks Mountain. In the higher parts of the Pigeon Hills, in the Gettysburg quadrangle, the probable equivalent of these beds is mapped with the Hellam conglomerate member of the Chickies quartzite.

Most of the ridges of Weverton sandstone in South Mountain are nearly straight massive mountains which trend northeastward, with the prevailing strike of the rocks, and have precipitous southeastward-facing escarpments and more gentle northwestern dip slopes. Snowy Mountain, an exception, is a flat-topped massive mountain trending southeast, with its prominent escarpment facing northeast.

Correlation.—The formation was named from Weverton, Md., where the South Mountain ridge composed of it is severed by the gorge of the Potomac. It is reported by Keith to have a thickness there of about 500 feet. The quartzite ridges extend from the Potomac northward into the Fairfield quadrangle, where the formation has the same lithologic character and position. It is not known to be fossiliferous, but it conformably underlies sandstones that contain Lower Cambrian fossils, and it is undoubtedly part of the basal Cambrian sediments.

HARPERS SCHIST WITH MONTALTO QUARTZITE MEMBER

Character and thickness.—The Harpers schist, which is normally a gray hackly sandy phyllite or schist, is largely replaced in the northern part of these quadrangles by the Montalto quartzite member, which expands from thin beds in the southwestern part of the area to thick massive beds that make up almost the whole formation in the northern part of the area. The schist is seen in but few outcrops in the South Mountain area, as it occupies slopes and valleys which are covered by débris from the harder quartzite beds. The general exposures where the rock is weathered show only fragments of hackly black slate, banded with white, gray schistose sandstone, and thin beds of hard dark ferruginous sandstone. Some of the schistose sandstone is thickly studded with small octahedrons of magnetite. The schist in places has a greenish color due to the sericitic mica present. Just beyond the southwest corner of the Fairfield quadrangle, on the road from Waynesboro to Monterey, the formation is a dark hackly slate or fine schist with thin sandy schist layers and a bed of white quartzite, about 10 feet thick.

The schist and slate are shales which have been metamorphosed by compression. The more purely argillaceous beds were altered into hackly slate or phyllite, but none were pure enough to produce a slate with good cleavage. In most places the altered rock is a fine schist, the impurities having been changed to sericite. This mineral is arranged parallel to the planes along which movement of the particles took place during compression and gives the rock its schistose character. Because of the poor exposure of the schist it has been mapped chiefly by tracing the depressions that mark the positions of the softer beds above and below the medial quartzite.

At about the middle of the formation there is a hard white quartzite called the Montalto quartzite member. It is not so resistant as the Weverton sandstone and consequently does not make such prominent ridges, and its outcrop is usually marked by numerous loose masses of rock with a few ledges. The quartzite is only 20 feet thick at the southwest corner of the Fairfield quadrangle but thickens rapidly northeastward on the west side of Green Ridge and constitutes nearly all of the formation at the north end of the ridge. North of the Carbaugh-Marsh Creek fault thin slate or shaly sandstone at the top and bottom of the formation are the only softer beds of the Harpers type present on Big Pine Flat Ridge. These beds are not exposed to view but are indicated by linear valleys and saddles. On East Big Flat Ridge and Piney Mountain even the soft beds at the base seem to be entirely replaced by sandstone, and no depression occurs at this horizon.

In the best exposures the Montalto member is seen to comprise two divisions—the lower, a thick series of white vitreous quartzites; the upper, massive beds of softer white sandstone containing numerous straight slender scolithus tubes, 10 inches and more in length. Many of the beds of the lower division are streaked and cross-bedded, with fine black partings stained red by iron oxide. Others of these lower beds are light gray and veined with white quartz.

In the Pigeon Hills, in the eastern part of the Gettysburg quadrangle, only one good exposure of Harpers schist was seen. In the road up the mountain, at the schoolhouse 1 mile northeast of Bittinger station, a few feet of soft gray to purple shale overlies the scolithus-bearing Chickies quartzite.

The Harpers schist in the hills south of the limestone valley at Hanover is a fine gray smooth sericitic schist or phyllite which weathers to pinkish-buff soft shaly particles. Some of the rock freshly exposed in a quarry is compact dark-blue sandy schist with hackly cleavage and rust-stained joints. Some beds are more quartzose, and the rust-stained quartzite quarried just east of the area somewhat resembles certain ferruginous quartzite beds in the Antietam.

The thickness of the formation at Harpers Ferry, W. Va., the type locality, where it is all slate, was estimated by Keith as 1,200 feet. In the adjacent Chambersburg quadrangle its thickness, including about 750 feet of the Montalto quartzite member, is about 2,750 feet. In the Fairfield quadrangle the thickness is estimated to be 3,000 feet, of which quartzite constitutes about 75 per cent in the greater part of the area. In the Pigeon Hills it is estimated to be about 1,000 feet thick.

Distribution and surface form.—The Harpers schist, with the Montalto quartzite member, is in general found on the crests and western slopes of the higher ridges of South Mountain. The schist occupies narrow valleys and depressions between ridges and knobs of sandstone, one generally at the base of the formation between ridges of Weverton sandstone and Montalto quartzite and another at the top of the formation between ridges of Montalto quartzite and Antietam sandstone.

In the southwest corner of the Fairfield quadrangle and the adjacent part of the Chambersburg quadrangle the structure is well brought out by these parallel curved ridges and valleys. (See fig. 11.) Farther north, on the west side of Green Ridge, the Montalto quartzite member forms two lines of knobs and ridges, due to two sandstone beds, which apparently coalesce at the north end of the ridge.

The largest mass of the formation is that which forms Big Pine Flat Ridge and the associated spurs in the northwest corner of the area. The thin upper schist of the formation occupies a narrow depression back of the line of knobs of Antietam sandstone which form the northwestern foothills. The long spurs that lead up to the crest of the mountain are composed of the white sandstone of the Montalto member, which is much thicker in this region. The rocks are gently folded but have a general low dip to the northwest, so that the deep ravines apparently do not cut through the formation. In the deepest part of the gorge of Shirley Run certain sheared coarse sandstones may represent the Weverton sandstone, but they are not so mapped. Around the mass of Weverton sandstone that forms Big Flat Ridge the lower schist of the Harpers formation makes a line of small valleys and ravines.

The Montalto quartzite member on the east side of this mountain mass dips more steeply and occupies a narrower belt of rounded knobs and short ridges, paralleled by a series of valleys on the upper schist of the Harpers. Two other long belts of the formation lie east of this mass, one of which forms East Big Flat Ridge and the other forms the western part of Piney Mountain. The lower schist of the formation seems to be entirely replaced by sandstone in these belts, for the fragments of scolithus-bearing white quartzite of the Montalto merge with those of the coarse feldspathic quartzite of the Weverton on the upland surface, and there are no linear depressions or valleys between. The position of the upper schist, however, is still represented by a small depression in the Mountain Creek valley at the north edge of the area.

Dark banded Harpers schist is present in the syncline on the north slope of Jacks Mountain, and in the small ridge just north of Iron Springs station it is associated with white quartzite, probably Montalto. A similar dark schist associated with vitreous white scolithus-bearing quartzite forms the western slopes of the Pigeon Hills in the eastern part of the Gettysburg quadrangle, and the schist is mapped as Harpers. Harpers schist also occurs in the southeast corner of the quadrangle, south of the Hanover Valley.

Correlation.—The Harpers schist takes its name from Harpers Ferry, W. Va., where bluish-gray to rusty-gray hackly slate or fine schist of this formation is exposed in the gorges of Potomac and Shenandoah Rivers. This belt of schist extends several miles into Maryland but is terminated by a fault before it reaches the Pennsylvania State boundary. An eastern belt of the same formation occupies the western part of South Mountain in Maryland and southern Pennsylvania and enters the Fairfield quadrangle at its southwest corner. As described by Keith, the formation is a uniform shale or schist from the type locality southward, but sandy layers come in at several horizons toward the north. They are not a conspicuous feature of the formation in Maryland but increase in thickness northward and in the Fairfield quadrangle form a zone of sandstone sufficiently resistant to produce mountains.

The schist mapped as Harpers in the Pigeon Hills has the characteristics of that formation and is associated with rocks of Antietam, Montalto, and Weverton type. The schist in the southeast corner of the Gettysburg quadrangle could not be identified with certainty in this area, but sections of similar rocks exposed in the Susquehanna River gorge south of Columbia and elsewhere establish the correlation of this schist with the Harpers.

No fossils except casts of *Scolithus linearis* have been found in the formation, but it is known to underlie sandstones that contain a Lower Cambrian fauna, and it is therefore regarded as of Lower Cambrian age.

CHICKIES QUARTZITE

Character and correlation.—The Chickies quartzite is chiefly a hard white scolithus-bearing quartzite that is similar to the Montalto and lies beneath a schist similar to the Harpers. It is exposed on the west flank of the Pigeon Hills at the east edge of the Gettysburg quadrangle and would have been mapped as the Montalto member of the Harpers schist if it were not directly connected through the Pigeon and Hellam Hills with thick quartzites exposed farther east in the Susquehanna gorge and there called Chickies. The Chickies and Montalto quartzites are regarded by the writer as synchronous deposits of pure quartz sand interbedded in less pure sand and clay of the Harpers and brought into the sea from some locally uplifted land mass. The Montalto is lenticular, being thickest in Big Pine Flat Ridge, in the northwest corner of the Fairfield quadrangle, thinning southward to almost nothing at the Maryland State line and becoming very thin at the north near Mount Holly Springs. The inclosing Harpers schist thins to almost nothing where the Montalto has its greatest thickness, and in places no Harpers schist is present at the base between the Montalto quartzite and the Weverton sandstone. The Chickies quartzite is also somewhat lenticular, thickening northeastward from the Gettysburg quadrangle. The relations of the two quartzites are shown in Figure 5.

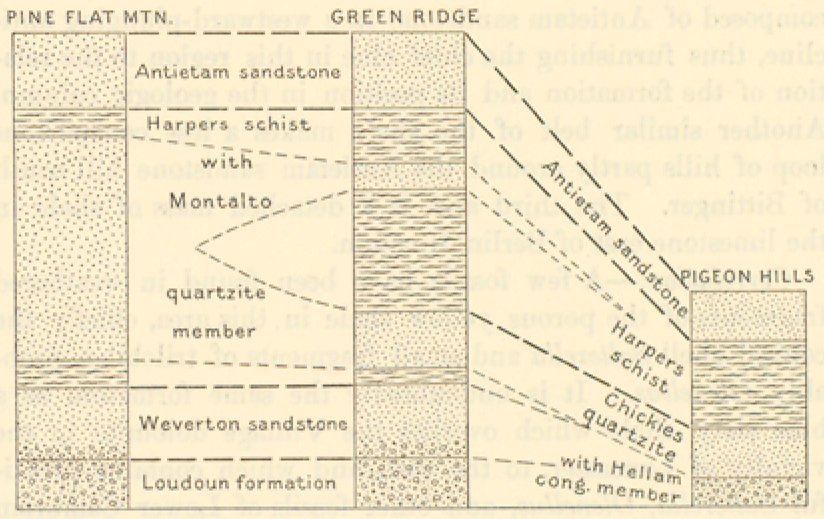


Figure 5.—Sections showing the probable correlation of the Cambrian quartzite and schist in the Pigeon Hills with the equivalent formations in South Mountain

Basal beds in the Hellam Hills, which contain coarse conglomerate, arkose, and some black slate, are separated as the Hellam conglomerate member, and that name is applied to the basal conglomerate-bearing beds in the Pigeon Hills of the Gettysburg quadrangle. They are probably the equivalent of the Loudoun formation and the Weverton sandstone of South Mountain. The Hellam member rests on pre-Cambrian volcanic rocks, like the Loudoun formation of South Mountain.

The Chickies quartzite in the type locality is about 1,000 feet thick, of which the Hellam conglomerate member makes up at a maximum about 600 feet. In the Gettysburg quadrangle the thickness can not be accurately determined. The scolithus-bearing quartzite is well exposed on the road into the Pigeon Hills northeast of Bittinger, where its thickness is estimated to be about 500 feet. The Hellam conglomerate member composes the main mass of the hills in this quadrangle and is estimated to be 300 feet thick.

ANTIETAM SANDSTONE

Character and thickness.—The Antietam sandstone is the uppermost of the mountain-making formations of South Mountain. It is a pure coarse-grained quartzose sandstone composed of two distinct members—a lower dense, resistant quartzite, in places bluish to pink, and an upper granular white or pinkish rock with numerous scolithus tubes.

The lower rock is a ridge maker and weathers into resistant blocks, which mantle the tops and outer slopes of the mountains. Some of the upper beds are cemented by calcium carbonate and weather readily into cream to buff sand, which is dug for use in building. Some of the upper quartzose beds have rusty partings that show molds of fossils. The uppermost layers of the formation on the west slope of South Mountain are composed of quartz grains in a matrix of fine white siliceous clay, and this material merges into very fine white siliceous sericite schist, which disintegrates to shaly clay. The highest bed seen on the east side of Big Flat Ridge is a conglomerate of bean-shaped white quartz pebbles in a fine sandy matrix.

The thickness of the Antietam sandstone in the Fairfield quadrangle is in general about 800 feet. On the western slope of Green Ridge, near the southwest corner of the quadrangle, and beyond to the south it appears to be very thin, its position being indicated in places only by fragments of porous coarse sandstone with rust-stained partings that are marked by molds of fossils, but this apparent thinness is probably due in part to faulting which cuts out part of the formation. On the geologic map in the Mercersburg-Chambersburg folio it was shown as entirely faulted out in this vicinity, the Harpers schist being indicated as thrust against the Tomstown dolomite. In the Pigeon Hills the formation is probably not over 500 feet thick.

Distribution and surface form.—The Antietam sandstone has a rather scanty distribution in the Fairfield and Gettysburg quadrangles. Its largest and most representative belt of outcrop is the line of hogback ridges southeast of Big Pine Flat Ridge. This belt enters the Fairfield quadrangle north of the Chambersburg pike and runs northeastward to its termination in Rocky Knob. The line of hills is cut by numerous deep transverse valleys into short ridges which have steep east slopes that conform nearly to the dip of the rocks and which are joined to the main mountain mass on the west by gentle saddles. The gaps through the ridges are very narrow, steep-sided, and rocky, and the twofold character of the sandstone is generally shown by distinct ledges or rock taluses of each bed. Isolated outcrops of similar quartzite that form the knob between Long Pine Run and Birch Run, the small hill at the forks of Hosack Run, and another in the small valley toward the southwest, at the edge of the quadrangle, are probably remnants of the same formation preserved on the east limb of a sharp syncline adjacent to an overthrust fault.

The narrow area of the Antietam sandstone in the extreme northwest corner of the Fairfield quadrangle is part of a continuous band that forms the line of foothills along the whole west side of this part of South Mountain. (See pl. 6.) Another small mass of the formation forms Grave Ridge and associated small ridges and knolls in the valley of Mountain Creek, at the north border of the quadrangle.

In the narrow band mapped on the east side of Antietam Cove only fragments of the sandstone were seen on the lower slope of the mountain, and the formation is probably either partly faulted out or weakened by crushing and faulting. Porous fossiliferous sandstone of the Antietam occurs in the foothills of the Pigeon Hills at the eastern edge of the Gettysburg quadrangle. It forms the lower western spurs of the hills and two outlying foothills to the south, the Hershey Hills, which just enter the Gettysburg quadrangle. It overlies schist of Harpers type and scolithus-bearing Chickies quartzite, probably equivalent to the Montalto. The sandstone is fossiliferous and otherwise resembles the fossiliferous sandstone of the Antietam on the west slope of Green Ridge, and it is therefore mapped as Antietam.

Correlation.—The Antietam sandstone was named from Antietam Creek, in the Harpers Ferry quadrangle, in the valley of which good exposures of the formation occur. It there has a thickness of 500 feet. It is not continuously exposed along South Mountain to the Fairfield quadrangle, owing in part to faulting and probably in part to the fact that pure sand was not everywhere deposited, but the character and position of the formation here described are identical with those of the Antietam, and their equivalence is established. It is known to extend continuously beyond the Fairfield quadrangle to the northeast end of South Mountain, near Dillsburg. Like the Montalto quartzite it increases from a thin discontinuous bed in Maryland to a persistent thicker sandstone toward the northeast.

A few fossils were found by Walcott in the scolithus-bearing sandstone and associated sandy shales of the formation on the Baltimore pike just beyond the southwest corner of the Fairfield quadrangle. These comprised a small shell, *Camarella minor*, fragments of the trilobite *Olenellus*, and *Hyolithes communis*. The same species occur in similar sandstones along the mountain front at Eakles Mills, Md., and at Mount Holly Springs, in the Carlisle quadrangle, Pa. *Olenellus* fragments and poorly preserved *Obolella* shells were found in porous sandstone fragments of this formation on the mountain slopes southeast of Antietam Cove, on the north side of Conococheague Creek at the west edge of the Fairfield quadrangle, and in the foothills of the Pigeon Hills. These fossils determine the age of the formation to be Lower Cambrian.

TOMSTOWN DOLOMITE

Character and thickness.—The few exposures of the Tomstown dolomite, the lowest of the formations of the Shenandoah group, in the Fairfield quadrangle give a very incomplete idea of the composition of the formation, showing only coarse glistening gray dolomite. From outcrops in adjacent portions of the Chambersburg quadrangle the formation is seen to be composed largely of dolomite and limestone, with considerable shale interbedded in the lower part. The dolomite is mostly gray with some darker-gray streaks, and some of it has a fetid odor. Thin-bedded dark-blue limestone occurs near the middle of the formation. Fine white siliceous sericitic slate or schist interbedded with dolomite is exposed at the base of the formation in old iron pits close to the Antietam sandstone, and some gray shale near the base is similarly exposed in a railroad cut. The uppermost beds of the formation, just beneath the siliceous rock at the base of the Waynesboro formation, are blue, laminated, somewhat magnesian limestone containing a small amount of black chert.

On account of the relatively soluble character of the formation it forms a depression between South Mountain and an irregular line of low ridges and knobs of the Waynesboro formation farther out in the valley. Its thickness determined near Tomstown, in the Chambersburg quadrangle, is about 1,000 feet, and this seems to accord with the exposure of the formation in Antietam Cove, in the Fairfield quadrangle.

Distribution and surface form.—The Tomstown dolomite forms valleys at the foot of the Antietam sandstone ridges. Only five small areas of the formation are shown on the map. The largest is a wedge-shaped area occupying most of Antietam Cove. A small area in the extreme northwest corner of the Fairfield quadrangle is part of the larger belt of the formation that follows the foot of this mass of South Mountain. The mapping of the small area in the valley of Conococheague Creek, the longer area back of Yellow Ridge, and the narrow area in the valley of Mountain Creek is based solely on the topography and the adjacent formations and on the presence of iron-ore deposits, as no limestone is exposed at these places. Limestone of the formation has been quarried in the Mountain Creek syncline at Pine Grove Furnace, not far north of the quadrangle. It is there a blue limestone with wavy mottling of darker magnesian layers veined with calcite, and some crystalline layers.

Correlation.—The formation was named from the small village of Tomstown, in the Chambersburg quadrangle. The few fossils that have been found in it include *Salterella*, from the upper beds of limestone near the type locality, and *Kutorginia* sp. and fragments of the trilobite *Olenellus*, from the valley of Little Antietam Creek, in the Hagerstown quadrangle. These forms determine the age of the formation to be Lower Cambrian.

WAYNESBORO FORMATION

Character and distribution.—The Waynesboro formation is a series of grayish calcareous sandstones, hard purple to red shiny shales, and minor limestones, which overlie the Tomstown dolomite and form a line of hills and knobs in the limestone valley. The formation barely enters the Fairfield quadrangle in Antietam Cove, and its description is taken from that of the adjacent outcrops in the Chambersburg quadrangle.

At the base is a very siliceous gray limestone, which weathers to slabby porous sandstone and forms a separate ridge where the dip is low. The residual sandstone slabs and associated large round masses of rugose chert and fragments of white vein quartz cover the outer or dip slopes of these hills. In places the sandy strata weather to minutely laminated iron-stained contorted glistening cherty rock with cavities filled with beautiful drusy quartz.

Several hundred feet of dark-blue limestone, dolomite, and fine-grained white marble in the middle of the formation form a valley between the sandstone ridges. The limestone becomes siliceous toward the top and merges into mottled slabby sandstone and dark-purple siliceous shiny shale, which form an outer ridge. These upper shales and slabby sandstones are ripple marked and show many indications of irregular bedding and current action.

The thickness of the formation in the Chambersburg quadrangle is approximately 1,000 feet. Only a part of this thickness is exposed in the Fairfield quadrangle.

Correlation.—The formation was named from the town of Waynesboro, in the Chambersburg quadrangle, where it is excellently exposed in two parallel concentric ridges with a limestone valley between. In sandy shale at the very top of the formation at Waynesboro *Obolus* (*Lingulella*) sp. undet. was found. No other fossils were found in this region, and this shell suggests the Middle Cambrian age of the formation. Middle Cambrian trilobites also occur in the limestones that immediately overlie and merge into the purple shales at Waynesboro. In central Virginia a bright variegated shale at this horizon, called the Watauga ("Buena Vista") shale, contains a trilobite formerly identified as a Lower Cambrian species but now regarded as probably Middle Cambrian. The Waynesboro formation is at present classified as Lower and Middle (?) Cambrian.

LIMESTONES OF THE MIDWAY-HANOVER AREA

Four formations have been distinguished in the limestone area in the southeastern part of the Gettysburg quadrangle. Overlying the Antietam sandstone in the foothills of the Pigeon Hills, previously described, are the Vintage dolomite, Kinzers formation, Ledger dolomite, and Conestoga limestone. The first three are probably equivalent to the Tomstown dolomite.

VINTAGE DOLOMITE

Character and distribution.—Just above the Antietam sandstone occur light-blue limestone and dolomite mapped as the Vintage dolomite. The formation is poorly exposed, as it occupies a lowland deeply covered with soil, only small outcrops being seen on the slopes of ridges of the overlying shale. It is quarried in a few small pits, and the beds seen are thin bedded and impure. The formation is estimated to be 500 feet thick.

It crops out in only two areas in the Gettysburg quadrangle, one east and the other south of Bittinger. Each area lies between hills composed of Antietam sandstone and a semicircular line of hills of overlying Kinzers shale.

Correlation.—No fossils have been found in this formation in the area. It occupies the same position as fossiliferous dolomite that lies between Antietam sandstone and a fossiliferous shale in the Kinzers formation in the vicinity of York and Lancaster, to the east, and is undoubtedly to be correlated with that bed. It was named Vintage dolomite from a village in Lancaster County, where the rock is exposed in a cut on the main line of the Pennsylvania Railroad. It is equivalent to the lower part of the Tomstown dolomite.

KINZERS FORMATION

Character and distribution.—Overlying the Vintage dolomite is soft calcareous shale, which weathers to porous rusty shale fragments that form low hills. Fresh fragments are slightly greenish gray and somewhat spangled with fine sericite. It weathers readily to buff and delicate pink porous shale, some layers of which are harder and somewhat sandy. The thickness of the formation is estimated to be about 50 feet, but only about 20 feet has been observed.

There are three areas of the formation in the Gettysburg quadrangle. Just east of Bittinger low shale hills form a more or less continuous loop around the end of the Hershey Hills, composed of Antietam sandstone in a westward-plunging anticline, thus furnishing the chief clue in this region to the relation of the formation and its position in the geologic column. Another similar belt of the shale makes a less conspicuous loop of hills partly around the Antietam sandstone hill south of Bittinger. The third area is a detached mass of shale in the limestone east of Berlin Junction.

Correlation.—A few fossils have been found in weathered fragments of the porous yellow shale in this area, chiefly the conical shell *Salterella* and small fragments of trilobites, probably *Olenellus*. It is undoubtedly the same formation as a blue slaty shale which overlies the Vintage dolomite in the vicinity of Lancaster, to the east, and which contains plentiful *Salterella*, *Olenellus*, and other fossils of Lower Cambrian age. Together with associated impure limestones it was named Kinzers formation, from a small village on the Pennsylvania Railroad just east of Vintage. Similar Lower Cambrian forms occur in the upper beds of the Tomstown dolomite in the Chambersburg quadrangle, and the Kinzers formation is probably to be correlated with part of the Tomstown.

LEDGER DOLOMITE

Character and distribution.—The rock immediately above the Kinzers formation is a dolomite which is poorly exposed because it crops out in a lowland deeply covered with soil. The few outcrops seen consist of a hard, knotty dark-gray dolomite, similar to the Tomstown dolomite of Cumberland Valley and to some of the beds in the Vintage dolomite. This bed is overlain by pure limestone and dolomite of the Ledger type, which are extensively quarried at Bittinger, at Centennial, and east of Irishtown. In the quarries granular crystalline gray dolomite merges laterally into high-calcium marble, which is mottled blue and white. The white marble is a little more coarsely crystallized and is irregularly distributed in and merges with the blue. It is apparently the product of recrystallization during metamorphism. The dolomite similarly is apparently a product of dolomitization of the pure limestone. Such an origin accounts for the irregular distribution of the pure calcium carbonate rock in the quarries. The total thickness of the pure beds can not be determined. In the Stacy & Wilton quarry, where the bedding is still preserved, a thickness of 300 feet of pure limestone is exposed. The pure upper beds of the formation are limited to three narrow belts—a very narrow winding area extending north from Bittinger, a wider band running southwest from a point near Red Hill School to Irishtown, and a small area at Centennial. The formation as a whole occupies a large part of the limestone area north of Edgegrove and west of Bittinger. Its thickness can not be accurately determined but is estimated to be about 2,000 feet.

Correlation.—Fossils were found in an impure banded layer just below the high-grade limestone in the Stacy & Wilton quarry. These fossils were the brachiopod *Nisusia festinata* Billings, which indicates Lower Cambrian age and probable equivalence to the upper part of the Tomstown dolomite of Cumberland Valley. The formation is the direct equivalent of the pure dolomite and high-grade limestone of the York and Lancaster area and takes its name from Ledger, a small village east of Lancaster.

ORDOVICIAN SYSTEM

CONESTOGA LIMESTONE

Character and distribution.—The Conestoga limestone is an impure blue limestone that occupies the lowland about McSherrystown. Few outcrops of the limestone can be seen, as the formation weathers readily to deep yellow sandy clay soil containing many small fragments of quartz and shale. The larger portion of the area has no outcrops, and the sequence of the beds can not be fully determined.

At its base is a black to dark-gray shale and a very impure limestone that weathers to a buff earthy sandstone; these beds make a low ridge that is more or less continuous along the north border of the formation. They form the conspicuous hill at Conewago Chapel and here contain a thin bed of quartzitic sandstone. They also make the low hill east of Centennial and another 1 mile northeast of Edgegrove, where they pass out of the Gettysburg quadrangle.

The limestone that overlies the shale is poorly exposed in most places, but west of Brushtown hard blue dolomite and coarse white to pink marble are exposed and considerable hard white chert and siliceous limestone are found in the soil locally.

The next traceable bed is a light-gray even-grained sandy limestone that weathers to coarse porous buff sandstone which is dug for building sand at several places. It is interbedded with impure blue limestone and some black shale. It makes a more or less continuous band across the area, as shown on the economic-geology map, but is most conspicuous on a low ridge between McSherrystown and Midway and another west of Brushtown, where it is dug for sand. (See pl. 5.)

The rest of the formation is chiefly compact, thin-bedded, very impure dark limestone, with some light banding, which rapidly weathers buff and at the surface soon passes into buff sandy clay soil. It has been quarried at several places, but even the quarry face in abandoned quarries disintegrates into soil after a short time, and few exposures can be seen. Around Lefevre the limestone contains glassy sand grains and contorted partings of shiny black shale and weathers to yellow soil containing many fragments of black shale and soft buff shale and quartz. Some of the sandy beds are fine limestone conglomerates with round grains of glassy quartz.

The formation occupies all of the lowland south of the shale hills at Edgegrove and extends to the Harpers schist hills in the southeast corner of the area. Its thickness can not be ascertained, as the bedding is nearly everywhere obliterated and replaced by cleavage, but it is probably over 1,000 feet thick.

Correlation.—No fossils have been found in the formation in this area. As shown on the map and as observed in the area to the east the basal shale unconformably overlaps the edges of the Ledger dolomite, Kinzers formation, and Vintage dolomite. It has been traced eastward into similar thin-bedded impure blue limestone which is called the Conestoga limestone and which is also unconformable on the Cambrian formations. Fossils found in this limestone in the vicinity of York determine its age as Ordovician, probably Chazy. It was named from Conestoga Creek, at Lancaster, where it is well exposed.

BEEKMANTOWN (?) LIMESTONE

Character and distribution.—Limestones are exposed in the lowland east of South Mountain about Fairfield, where the cover of Triassic sandstones has been removed by erosion. The outcrops are so largely concealed by stream alluvium, mountain wash, and residual soil that the details of their character and relation can not be clearly determined nor their thickness measured. The limestone around Marshall is a rather pure blue limestone finely laminated with impurities, with some white to pink marble, and closely resembles the Beekmantown of the Cumberland Valley. It has been quarried and burned for lime at several places. Limestone locally exposed near Virginia Mills is earthy and weathers to buff shaly fragments and tripolite and thus resembles the Elbrook limestone of the Cumberland Valley, but it is not separately mapped. The limestone area is more than 3 miles wide at Fairfield and narrows gradually northward. South of Middle Creek the limestone is thinly covered by limestone conglomerate of Triassic age, and small areas of the Beekmantown (?) limestone may be locally uncovered in the area mapped as Triassic conglomerate.

Correlation.—As fossils have not been found in the limestone about Fairfield, no positive correlation with the formations in the Cumberland Valley can at present be made. Lithologically most of it resembles the Beekmantown so closely that this name is tentatively applied to it. The fact that fossiliferous Beekmantown limestone is present in the valley around Frederick, Md., about 25 miles to the southwest, similarly exposed at the western edge of the Triassic rocks, favors this correlation. It is possible that the earthy limestone around Virginia Mills may prove to be Conococheague or Elbrook and should be separated from the Beekmantown.

TRIASSIC SYSTEM

NEWARK GROUP

GENERAL CHARACTER AND DISTRIBUTION

The Newark group in the Fairfield-Gettysburg area is composed largely of interbedded soft red argillaceous shale and friable fine red sandstone, with numerous beds of gray, white, green, and buff sandstone, some of which are arkosic. Locally there are beds of fine red calcareous conglomerate, dark-gray to black and green shale, rounded quartz-pebble conglomerate, thick coarse conglomerate composed largely of pebbles of quartz and Cambrian quartzite, and limestone conglomerate.

Two formations of this group are recognized in the Fairfield and Gettysburg quadrangles—the New Oxford formation and the Gettysburg shale. They correspond in a broad way to the Stockton and Brunswick formations in New Jersey and eastern Pennsylvania, the intervening Lockatong formation being absent. A harder sandstone-bearing member and quartzose and limestone conglomerate lentils have also been mapped.

The Newark group covers about half the surface of these quadrangles. It occupies all the area southeast of South Mountain except a small lowland around Fairfield, where it has been eroded so that the underlying limestone is exposed, several belts of intrusive igneous rocks, and the southeast corner of the Gettysburg quadrangle, where older rocks crop out. This large area is part of a belt of Triassic red rocks which extends from southern New York into Virginia. The dip of the beds in this area is almost invariably to the northwest and ranges in general from 10° to 35°, with an average of about 20°. Locally, adjacent to intrusive bodies, dips as high as 50° have been observed. The total thickness, computed from the dips and width of outcrops, is about 23,000 feet. It is evident, however, from a study of the geologic map and Figure 6, illustrating the mode of deposition, that at no one place does this thickness of strata occur. The sediments were deposited in a long, narrow basin that progressively deepened westward, the first deposits being laid down only in the eastern part of the basin and later deposits spreading progressively farther west. Only a small part of the total thickness of sediments should therefore be found at any one place.

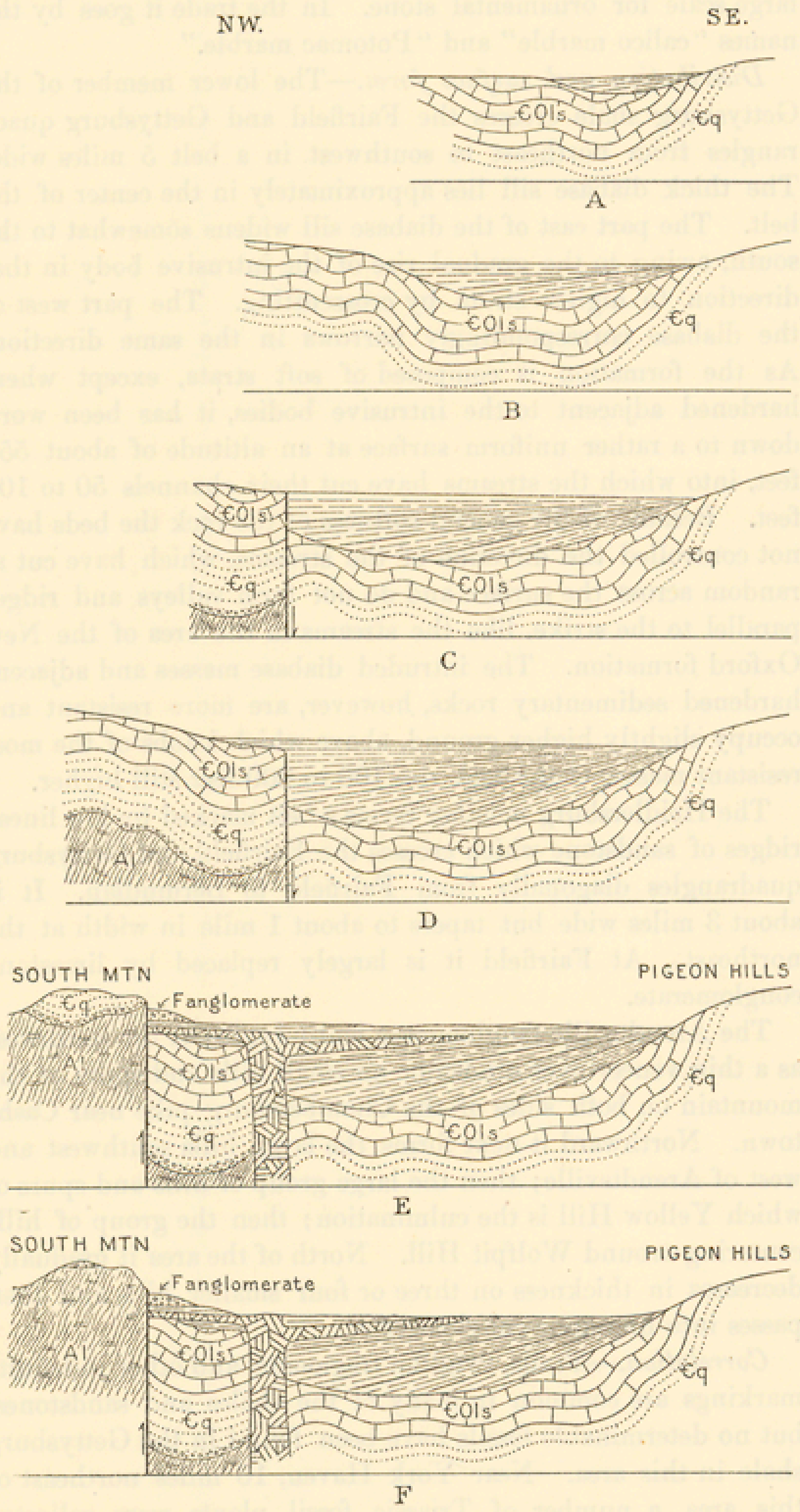


FIGURE 6.—Sections across the Triassic basin illustrating hypothetical mode of deposition of the sediments in a basin which gradually deepened by progressive subsidence at its west side, which tilted the recently deposited beds westward

The sediments were derived almost wholly from an uplifted land mass to the east composed of pre-Cambrian crystalline rocks and Cambrian quartzose rocks. The sinking of the basin was caused in part by faulting of the limestone floor near the west edge of the basin, as shown in sections C and D. Molten diabase invaded the basin, probably by way of this break in the floor, and penetrated the Triassic sediments as sills and dikes. South Mountain was later uplifted by faulting along a break at the western margin of the Triassic basin, and the waste from the erosion of the uplifted mass formed great alluvial cones of coarse fanglomerate on the predecessor of the Gettysburg Plain at the mouths of mountain gulches, as shown in section E. Further uplift of South Mountain quickened erosion, which removed most of the Cambrian quartzite from the mountain, as shown in section F. Al, Algonkian lava; €q, Cambrian quartzite and schist; €Ols, Cambrian and Ordovician limestones

From the fact that in New Jersey there are numerous strike faults which repeat strata, thus increasing their apparent thickness, the great thickness computed as stated above may be considerably in error, but as no evidence of appreciable faulting within the Newark area was observed, especially none parallel to the strike, this thickness must be accepted, in the present state of knowledge, as approximately correct. In New Jersey the thickness has been estimated by Kümmel[5] at 20,000 feet, and in eastern Pennsylvania, on Perkiomen Creek, the portion mapped in the Philadelphia folio is estimated by Darton to be between 10,000 and 13,000 feet thick, but this does not include a considerable thickness of the uppermost beds, which do not occur in the area mapped in that folio.

NEW OXFORD FORMATION

Character and thickness.—The New Oxford formation is composed of red shale and sandstone containing many beds of light-colored micaceous sandstone, arkose, and conglomerate, which distinguish it from the overlying formation. In the lower 3,000 feet conglomerates and arkosic beds are more common. On the north flank of the Pigeon Hills a thick conglomerate of coarse quartzose pebbles and boulders in a red sandy matrix lies at the base and extends into the Gettysburg quadrangle for about a mile. Another coarse conglomerate lentil of rounded white quartz pebbles in a red sandy matrix occurs a little higher in the section a short distance to the southwest. It is a hard resistant rock forming hills around Irishtown and passes northeastward into a bed of coarse hard light-gray sandstone containing only a few quartz pebbles.

Yellow and red mottled calcareous mudrock containing some gray limestone pebbles occurs at or near the base in most places southwest of the Pigeon Hills. Overlying this or interbedded with it is commonly a thin fissile black carbonaceous shale which contains shells of very small fresh-water animals. Some of the thicker red sandstones in the lower part of the formation are quarried for building stone here and elsewhere in eastern Pennsylvania.

The upper 4,000 feet is composed largely of soft red shale and sandstone, with scattered layers of light-colored sandstone. In the 500 feet near the middle gray to white micaceous sandstone beds are thicker and more numerous than in the rest of the formation. A composite section of the formation and a detailed section of the basal beds are given below.

Composite section of New Oxford formation in the Gettysburg quadrangle

	Feet
Chiefly red shale with some soft red sandstone, light-gray to white micaceous sandstone, and thin beds of fine calcareous conglomerate	2,200
Many thick-bedded light-gray to white coarse micaceous sandstones with some conglomerate, interbedded with red shale	500
Red and white sandy shale with a few beds of light-gray to white micaceous sandstone	1,300
Hard light-gray to green thick-bedded granular micaceous sandstone with some fine conglomerate	20–50
Red shale, with numerous markings, some dark-red sandstone	210
Gray to white hard micaceous sandstone	1–5
Red shale	420
Coarse white micaceous sandstone and quartz conglomerate with some 2-inch pebbles	1–5
Red shale and soft gray to red micaceous sandstone	980
Hard gray micaceous sandstone with some quartz conglomerate	1–25
Red shale with beds of soft red micaceous sandstone	460
Red shale	660
Hard conglomerate of large pebbles of rounded white quartz	1–5
Red shale, red and yellow conglomeratic calcareous mudrock, fissile black carbonaceous shale, and thin greenish-gray micaceous sandstone	115
Approximate total thickness	6,900

Detailed section of basal beds of New Oxford formation near Irishtown

	Feet
Conglomerate of 1 to 3 inch rounded white quartz pebbles in red matrix, indurated in most places to a hard, resistant pudding stone	1–5
Shale, not well exposed	20
Thin hard greenish-gray to reddish glistening micaceous sandstone	1–5
Soft red and yellow conglomeratic calcareous mudrock	40
Black carbonaceous fissile shale crowded with small bivalve shells, with some interbedded yellow earthy calcareous shale toward top	15
Red shale and soft micaceous sandstone containing beds of limestone conglomerate and calcareous shale	35

The upper limit of the formation is drawn where the light-gray micaceous harder sandstones cease to be prominent and softer red beds predominate. This line must be drawn arbitrarily in places, for the prominence of the sandstone outcrops differs from place to place, depending on the amount of weathering and soil cover. The line drawn on the map, therefore, may not be at exactly the same stratigraphic horizon throughout the area, but it is nearly so.

Distribution and surface form.—The New Oxford formation crops out along a belt 4 miles wide northwest of the McSherrystown-Hanover limestone lowland. Its general surface is a low plateau between 580 and 620 feet in altitude whose eastern front rises rather abruptly 50 to 100 feet above the limestone lowland. Portions of this surface are still flat and level, but much of it has been worn away by streams, which have cut valleys 60 to 100 feet deep. The sandstone beds, being more resistant than the soft shales of the formation, have directed the erosion largely into longitudinal valleys parallel to the northeast strike of the rocks and separated by low rounded ridges. The conglomerate and harder sandstone beds near the base form a small discontinuous ridge along the eastern border of the area. On the eastern slope of this ridge the soft black carbonaceous shale and basal calcareous conglomerate are generally exposed, but they are best shown near Irishtown and in the sections northeast of that place.

The shales weather to deep-red sandy clay soil striped by yellow and buff bands of sandy soil derived from the interbedded arkosic sandstones. On the flat upland surfaces, such as those about Germantown and east of Bonneauville, the soil is so deep that it is difficult to trace the individual sandstone beds, but on the slopes, where the soil has been more or less removed, rock fragments are numerous in the soil and outcrops occur in the road cuts, so that the beds can be readily traced. The belt of thicker gray sandstones in the upper part of the formation makes a low ridge that passes through Germantown and points just west of St. Luke's Church, half a mile west of Kohler School, and 1 mile west of New Oxford.

The formation is invaded by no large intrusive masses of diabase, and its rocks are therefore not altered to any extent by heat from such sources, but it is cut across by a few thin dikes of this rock, two of which are mapped. They can be traced only by the residual rounded fragments or balls of "ironstone" in the soil.

Correlation.—The New Oxford formation is not generally fossiliferous. Markings of various kinds, including trails of animals that crept in the mud, are common on the surface of many of the red shales. Fucoidal and twiglike impressions are also preserved in some of the sandstones. None of these, however, have been identified. The black fissile shale near the base of the formation is the only highly fossiliferous bed. It is crowded with small shells of a fresh-water phyllopod crustacean, which have been identified by T. W. Stanton as *Estheria ovata* (Lea). These fossils are so simple in form and surface features that they are of little value in age determination. The species was described from specimens collected from the Newark group at Phoenixville, Pa., and has been found in the same group, associated with coal, in North Carolina.

The formation occupies the same general stratigraphic position as the Stockton formation in eastern Pennsylvania and has somewhat the same lithologic character. The Stockton includes at the type locality in eastern Pennsylvania interbedded yellow micaceous feldspathic sandstone, coarse arkosic conglomerate, brownish-red sandstone, and soft red argillaceous shale, with the arkosic conglomerate and sandstone prevailing in the lower part. Its thickness is given by Kümmel as 4,700 feet. Its thickness near Norristown, Pa., is stated in the Philadelphia folio to be 3,500 to 4,000 feet, although if computed from the dips and outcrops it measures about 6,000 feet, an allowance of over 2,000 feet having been made by the authors of that folio for supposed repetition of beds by strike faulting. This thickness therefore compares favorably with that of the New Oxford formation mapped in the Gettysburg quadrangle. In a general way the two formations are undoubtedly equivalent, but as the Lockatong formation, which overlies the Stockton in southeastern Pennsylvania, thins westward and ends east of Elverson, the upper limits of the two formations can not be proved to be the same, and a new name is therefore given to the formation in this area. It is named from the town of New Oxford, where it is typically exposed.

GETTYSBURG SHALE

Character and thickness.—The upper formation of the Newark group, which is in general a thick red shale and soft red sandstone, is here described as the Gettysburg shale, from its exposures at and around Gettysburg. The formation is invaded by a great sill of diabase, about 1,800 feet thick, called the Gettysburg sill, which extends northeastward entirely across Adams County, and also by several large crosscutting bodies, dikes, and smaller sills. As a result of this invasion the bright-red shale of the unaltered formation is changed to dull red on the outer edges of the metamorphosed zone, becomes harder and darker toward the interior of the zone, and at the contact of the diabase mass is a dark-purple to almost black, hard, generally fragile argillite, which fractures irregularly and shatters into small angular pieces when struck with a hammer, though some of it is tough and resistant. Some of the beds, which may have been originally more or less calcareous are altered to light buff or white generally porous porcelanite. The metamorphosed sandstone beds are also generally light buff and porous.

Near the middle of the formation are many interbedded harder gray to white sandstones, and this part is separately mapped as the Heidlersburg member. At the top of the formation there are thick lenses of coarse conglomerate, most of which are composed of pebbles and cobbles of Cambrian quartzite, but in places where the upper beds of the formation overlap Paleozoic limestone the conglomerate consists of limestone pebbles in a red calcareous matrix. The quartzose conglomerate is mapped as the Arendtsville fanglomerate lentil, and the limestone conglomerate is also separately mapped.

Interbedded with the red shales of the lower member are soft red sandstone and minor quantities of white sandstone, green and yellow shale, black carbonaceous shale, and dark impure limestone. Some of the red sandstone contains small pebbles and grains of limestone, which weather out and leave the rock pitted. The following section of beds in the lower member of the formation, arranged in order from top to bottom, is given to show its variable character, but thicknesses were not determined.

Sequence of beds in lower member of Gettysburg shale

Red and yellow shale with a few red sandstones.
Thin bed of fine quartz conglomerate.
Dense black carbonaceous argillite and thin dark-gray to red impure limestone.
Chiefly soft red shale, altered by a thick intrusive sill of diabase to hard dark-purple, gray, and white argillite.
Red shale with a few beds of calcareous red sandstone containing small pebbles and grains of limestone.
Red shale and sandstone with a few harder gray to white sandstones.

The total thickness of this lower member of the formation, exclusive of the diabase sill, is about 7,500 feet.

The soft red shales of the upper member of the formation are poorly exposed in the northern part of the area, because they

[5] Kümmel, H. B., New Jersey Geol. Survey Ann. Rept. for 1896, p. 59, 1897.

occur in valleys between the hills of conglomerate and are deeply covered with gravel wash. About 2,000 feet below the top of the formation, east of Cashtown, there are beds of fine black carbonaceous shale and gray to rusty shaly, earthy sandstone which are distinct from the rest of the formation. They contain stemlike markings and seem to represent sediments deposited under conditions that favored the accumulation of coal. The upper member of the formation varies greatly in width of outcrop and therefore in thickness. The greatest thickness is 3,200 feet, as determined from dips and width of outcrop east of Cashtown.

The thickness of the whole formation, including the Heidlersburg and Arendtsville members but exclusive of the diabase sill, computed from dips and width of outcrop, is about 16,000 feet. The fact that the formation is disturbed by the intrusion of a large sill and several smaller irregular masses and dikes of diabase, makes the computation of thicknesses somewhat inaccurate, but unless there is considerable duplication by strike faults, which are not evident at the surface, this estimated thickness is probably nearly correct.

Heidlersburg member.—A member near the middle of the formation is composed largely of red shale and sandstone with some green, gray, and black shales, interbedded with many harder gray to white sandstones that constitute its distinguishing feature. It is well exposed in the vicinity of Heidlersburg, from which its name is derived. A composite section of the member is as follows:

Composite section of Heidlersburg member

	Feet
Dull-red and green shale and sandstone with numerous hard gray, green, yellow, and white sandstone beds	600
Hard red and light-gray to green shale, fissile in part, with some thin slabby sandstones and a few blue calcareous beds	900
Hard white sandstone	2–5
Red and dark-gray hackly shale	1,200
Hard light-gray sandstone	2–5
Thin-bedded red shale with some wavy to crumpled black shale	600
Hard white sandstone	2–5
Red, green, and bluish shale and compact argillite, suncracked, with a little black shale and sandstone	300
Hard red sandstone	2–5
Red shale	900
Hard gray to white sandstone	2–5
Red shale	300
Hard gray to white granular sandstone	2–5
	4,800

Numerous intrusions of diabase masses in the Heidlersburg member have altered some of the strata to hard white porcelanite and to white open-textured sandrock of light weight. Little of the baked shale is dark-purplish argillite, which is the common altered form of the Gettysburg shale. Near the western margin of the area occupied by the member certain quartzose beds have been changed to vitreous gray quartzite closely resembling the Cambrian quartzite, but the rock is brittle and breaks into small angular fragments which cover the fields and give them a light-gray color, as may be seen on the hills just south of Cashtown.

Arendtsville fanglomerate lentil.—A coarse conglomerate of rounded cobbles and boulders of quartzite, sandstone, quartz, and some aporhyolite in a matrix of red sand extends for 20 miles along the foot of South Mountain in the northern part of Adams County and adjacent part of York County. This rock is named the Arendtsville fanglomerate lentil from the exposures near the town of Arendtsville. The conglomerate is seen at few places as a firm rock, for it is so loosely cemented that it disintegrates rapidly, leaving the round cobbles thickly strewn over the surface and in the reddish sandy soil. Nevertheless the blanket of cobbles resists erosion, and the member generally forms high hills at the foot of the mountains.

The lentil has been deeply eroded and dissected so that it forms a scallop of somewhat semicircular hills extending out into the valley along the mountain front. The pebbles in the lower beds, exposed on the outer edges of the nodes and also in the reentrants between the nodes, are smaller and more scattered, and the conglomerate layers are interbedded with and grade into red sandstone. In the thicker and higher parts of these semicircular nodes the conglomerate is coarse. On the larger hills, such as Yellow Hill and Wolfpit Hill, the cobbles average 3 to 4 inches in diameter and are well rounded. Many are larger, as much as 8 or 10 inches, and some are more than 1 foot in diameter. Unusually large boulders of quartzite 2 feet in diameter are plentiful on the lower east slope of the Wolfpit Hill near Bream Mill. The large boulders are generally less well rounded, and some near the mountains are angular, evidently not having been transported a great distance.

Fragments of all the harder rocks now found in the adjacent South Mountain, except possibly greenstone, occur in these conglomerates. Most of the pebbles are fine-grained gray to white quartzite, some of which contain *Scolithus* tubes and were derived from the Antietam sandstone or Montalto quartzite. Other pebbles are coarse gray to purple sandstone and fine conglomerate derived from the Weverton formation, and some are milky-white vein quartz. Pebbles of aporhyolite are not generally common in the conglomerate but in places are abundant and even make up most of the rock. On the north side of Conewago Creek northeast of Bridgeport fragments of aporhyolite porphyry are so plentiful in the conglomerate that it was at first mistaken for a brecciated aporhyolite. In one place rather large slabs of aporhyolite occur in the conglomerate. Most of the pebbles of the conglomerate are stained red by iron from the red sand matrix.

At the southwest termination of the fanglomerate lentil, limestone pebbles are mixed with the quartzite pebbles, and the conglomerate is there more firmly cemented, owing to the calcareous nature of the cement. Scattered limestone pebbles also occur in the transition beds at the base of the fanglomerate on the outer edges of the hills and in the reentrants between the hills. In weathered ledges the limestone pebbles disintegrate to soft clay and in places are entirely removed from the rock, leaving a porous or pitted conglomerate. Some of the disintegrated conglomerate forms a light-yellow soil instead of red, the color being due chiefly to the calcareous matrix or cement.

The conglomerate hills are apparently remnants of a thick alluvial fan of coarse unassorted material derived from a gorge in the mountains on the west that were uplifted during the closing stages of the Triassic, and the lentil may therefore properly be called a fanglomerate. (See fig. 7.) The mountain stream that debouched upon the plain at this place evidently drained an area still covered by Cambrian quartzite, for it carried chiefly rounded fragments of that rock, whereas near the western edge, close to the uplifted mass, aporhyolite fragments are plentifully mixed with the quartzite fragments and came from the near-by mountain front, where the quartzite had been largely removed. Toward the south, around Fairfield, and also at the north in York County, where the conglomerates consist of limestone pebbles, the mountain streams evidently drained elevated areas on the west that were still covered with Paleozoic limestone.

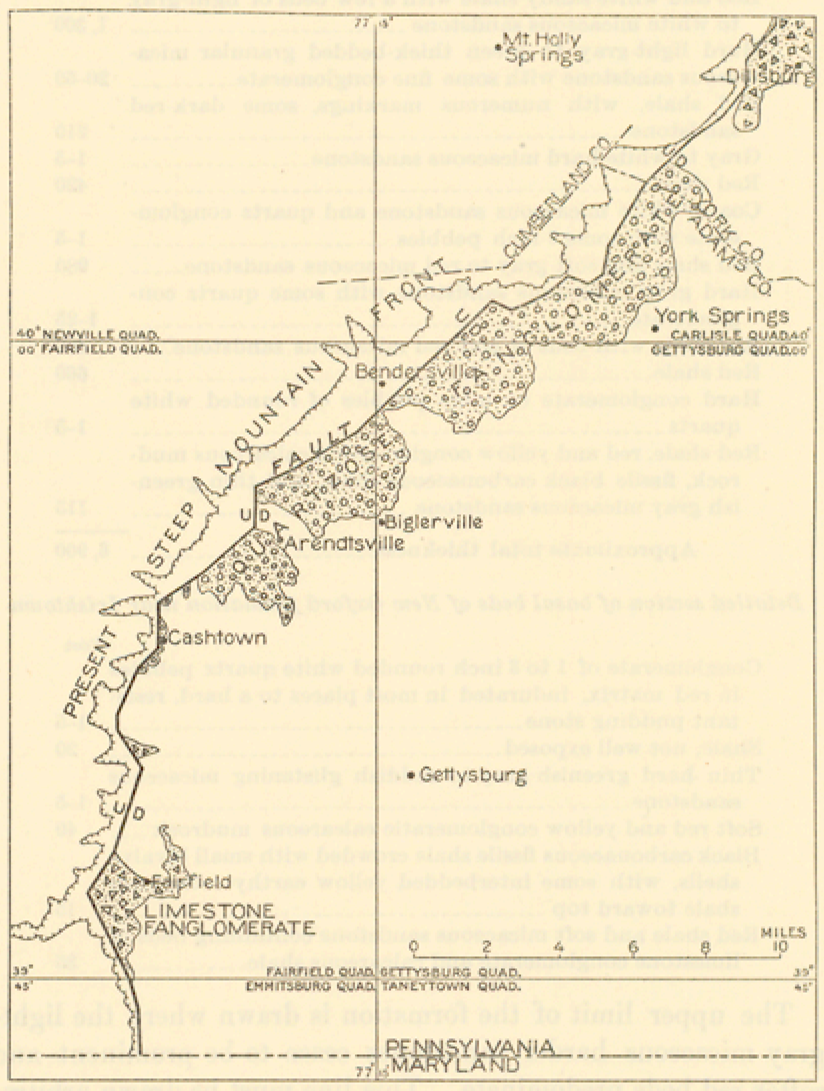


FIGURE 7.—Map showing distribution of Triassic fanglomerates and associated normal faults along foot of South Mountain in the Fairfield and Gettysburg quadrangles and adjacent area

The limestone fanglomerate indicates that at the time of faulting limestone still covered part of the uplifted mass to the west. The quartzose fanglomerate was derived from the part of the uplifted area from which the limestone had been eroded

The gravel is poorly sorted and apparently was not well bedded when deposited, for the attitude of the conglomerate beds can in few places be determined. Most of the observed dips are to the northwest, like those of the associated sandstones, but the conglomerate as a whole apparently lies nearly horizontal on the sandstone exposed on the lower flanks of the hills. The thickness is at least equal to the height of the hills above the plain and is estimated to be not less than 500 feet at its thickest point.

Limestone conglomerate lentil.—South of the Chambersburg pike small limestone pebbles appear in the conglomerate and upper beds of sandstone, but not in sufficient number to warrant calling the rock a limestone conglomerate. Three-fourths of a mile southwest of Orrtanna a conglomerate composed largely of limestone pebbles has been quarried for lime. Thence south to Virginia Mills and Fairfield the Paleozoic limestone is exposed and the limestone conglomerate, which probably once overlay it, has been removed by erosion. A narrow band of conglomerate appears on the west side of Sugarloaf, widens southward, and beyond Middle Creek underlies practically the whole lowland. Its outcrop narrows again to a slender band between McKee Knob and the foothills of Jacks Mountain, the narrowness being due in part to faulting.

The pebbles of the conglomerate average 2 to 3 inches in diameter, many being as much as 5 inches. They are largely composed of light and dark gray to pink fine saccharoidal marble, gray dolomite, and gray impure laminated limestone. The pebbles are generally rounded, although some are subangular. The matrix is red to gray calcareous clay or fine sand, which cements the pebbles into a compact rock. The limestone conglomerate has been quarried and burned for field lime at many places in the area but in general is too thin for extensive quarrying. The thickest beds seen are exposed in quarries east of Fairfield, where at most 20 to 25 feet is present. Southward in Maryland, especially near Point of Rocks, the conglomerate is thick and compact and has been quarried on a large scale for ornamental stone. In the trade it goes by the names "calico marble" and "Potomac marble."

Distribution and surface form.—The lower member of the Gettysburg shale crosses the Fairfield and Gettysburg quadrangles from northeast to southwest in a belt 5 miles wide. The thick diabase sill lies approximately in the center of the belt. The part east of the diabase sill widens somewhat to the south, owing to the gradual rise of the intrusive body in that direction to higher strata by crosscutting. The part west of the diabase correspondingly narrows in the same direction. As the formation is composed of soft strata, except where hardened adjacent to the intrusive bodies, it has been worn down to a rather uniform surface at an altitude of about 550 feet, into which the streams have cut their channels 50 to 100 feet. Because of the general softness of the rock the beds have not controlled the direction of the streams, which have cut at random across the surface and do not form valleys and ridges parallel to the strike, like the streams in the area of the New Oxford formation. The intruded diabase masses and adjacent hardened sedimentary rocks, however, are more resistant and occupy slightly higher ground, above which knobs of the most resistant masses of the rock rise 100 to 200 feet still higher.

The Heidlersburg member forms a belt marked by low linear ridges of sandstone which crosses the Fairfield and Gettysburg quadrangles diagonally from Fairfield to Bermudian. It is about 3 miles wide but tapers to about 1 mile in width at the northeast. At Fairfield it is largely replaced by limestone conglomerate.

The Arendtsville fanglomerate lentil begins at the southwest as a thin veneer over sandstone on small hills and spurs of the mountain on both sides of the Chambersburg pike near Cashtown. Northward it next forms the large hills southwest and west of Arendtsville; then the large group of hills and spurs of which Yellow Hill is the culmination; then the group of hills centering around Wolfpit Hill. North of the area it gradually decreases in thickness on three or four smaller hills and then passes into limestone conglomerate.

Correlation.—Trails, twiglike fragments, and other indefinite markings are common in many of the shales and sandstones, but no determinable fossils have been found in the Gettysburg shale in this area. Near York Haven, 10 miles northeast of this area, a number of Triassic fossil plants were collected from the Gettysburg formation and a small crustacean, *Estheria ovata* (Lea), was recently obtained by the writer in the same rocks at Middletown, Pa.

In eastern Pennsylvania and New Jersey dinosaurian tracks were found in the Brunswick shale, and similar tracks have been reported from red sandstones at Emmitsburg, Md. Dinosaurs and other land animals found in Triassic rocks of Connecticut and Nova Scotia determine the age of these red deposits as upper Triassic. The fanglomerate at the top of the formation was deposited after the mountain block to the west had been partly uplifted by fault movement and therefore is of latest Triassic age.

The formation which overlies the Stockton formation in New Jersey, called the Lockatong formation, is described by Kümmel[6] as comprising fissile carbonaceous shale, hard massive black and bluish-purple argillite that breaks into angular fragments, dark-gray to green flagstone, dark-red shale, and a few thin beds of impure black and drab limestone or calcareous shale. The black and purplish hard argillite, the most characteristic rock of the formation, although called by some "baked shale," is regarded by Kümmel as a weathered unmetamorphosed sedimentary rock, as it maintains this character over long distances where there is no evidence of intrusive rocks at the surface. In the Fairfield-Gettysburg area there are also hard dark argillite and rocks of similar character, but their color and hardness are plainly the result of metamorphism by the intrusive rocks, and they do not mark a particular horizon. The Lockatong formation has been traced from eastern Pennsylvania to a point about 10 miles west of Phoenixville, where it thins out and disappears. West of that point the soft red shale and sandstone of the Brunswick rest on the Stockton formation, and the division line is not so clearly marked. It is found, however, that the Gettysburg shale here described approximately represents the Brunswick formation, but the exact equivalence is not established. It is therefore

[6] Kümmel, H. B., New Jersey Geol. Survey Ann. Rept. for 1896, p. 40, 1897.

given the new name Gettysburg, from the town of that name where the formation is well exposed. In a recent report on the area around New Holland, Pa., there is an incidental reference to the Gettysburg formation in that area, but the formation was not described.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

TERRACE GRAVEL AND ALLUVIAL FANS

Character and distribution.—All along the foot of the steep slopes of South Mountain there is more or less accumulation ot wash brought down by streams and rivulets and deposited where their gradients change to gentle slopes. The wash from the smaller rivulets is generally too insignificant to be mapped. The typical form of the mappable mountain wash is a series of alluvial fans whose apexes are at the mouths of the mountain gorges and which extend out into the plain as raised platforms or terraces. There are only a few well-defined fans in the Fairfield-Gettysburg area; one of the most symmetrical and complete is the deposit at the mouth of the Little Marsh Creek gorge. Many of the fans coalesce and form broad aprons, as those on Toms Creek, Spring Run, and Middle Creek. Other deposits are elongated and reach far out into the valley as terraces bordering the streams, such as the Marsh Creek deposit, which probably was originally an elongated fan that reached Seven Stars but has since been cut in two by the stream and left as bordering terraces.

Along Conewago Creek the deposits of terrace gravel are perched on detached benches, mostly on the concave sides of the stream bends. They mark the former bed of the stream, which, by increasing its meanders as it cut its channel deeper, left the gravel-covered stream bed as terraces on the inner sides of the meanders. Some of the higher benches have sharp outlines, but most of them slope gently toward the stream and are mantled from top to bottom by gravel, which was deposited by the stream as it receded and gradually occupied lower levels. This condition is particularly well shown in the large bends east of Newchester, where the gravel covers not only the top of the terrace 70 feet above the stream but the gently sloping surface on the concave sides of the meanders down to the stream.

The alluvial fans are composed largely of rounded boulders and cobbles of the different mountain rocks. In the larger deposits the boulders are generally not more than 4 to 6 inches in diameter, but the steeper fans close to the foot of the mountain are composed largely of masses 2 feet and more in diameter. The gravel on terraces which extend far into the valley becomes finer and finer away from the mountain front. The material in the fans comprises rhyolite, greenstone, and various kinds of Cambrian quartzite, the material predominating in each fan being determined by the character of the prevailing rocks exposed in the areas drained. Thus the fan at the mouth of the Toms Creek gorge is composed largely of Cambrian sandstone, quartzite, and conglomerate; that at the mouth of the Little Marsh Creek gorge consists largely of rhyolite and greenstone boulders.

The gravel-covered terraces at the east foot of the mountains are mostly at altitudes of about 700 feet, although the steeper fans from the smaller ravines rise to greater heights. Few of the smaller ones are mapped. The stream terraces decline gradually away from the mountains, their slope representing the gradients of the old streams. The Marsh Creek bench descends to 560 feet at Seven Stars; the Conewago Creek bench descends to 600 feet at the eastern edge of the Fairfield quadrangle and to 500 feet east of Newchester.

Similar alluvial fans are developed on the west slope of South Mountain, but only a small area in the extreme northwest corner of the Fairfield quadrangle is occupied by these deposits. Here they mantle the surface of the limestone in a broad apron of coalescing fans from the small rocky gorges in the west slope of Big Pine Flat Ridge and are composed entirely of boulders and cobbles of the various kinds of Cambrian quartzite composing the mountain. The terrace on the west side of the mountain stands at an altitude of about 1,000 feet in this quadrangle but slopes rapidly down to 800 feet a short distance west of the mountain front. Quartzite cobbles in sandy soil cover the whole valley floor of Conococheague Creek and Antietam Cove, large flat-bottomed valleys that open out into the limestone plain to the west. These deposits are largely an old valley filling into which the present streams have cut their channels, leaving the gravel on low, gently sloping terraces.

Age.—No fossils have been found in these gravel deposits in the Fairfield-Gettysburg area. Probably the alluvial fans and mountain wash began to accumulate in the later part of the Tertiary period, when the land stood so near sea level that active erosion did not proceed below the plain on which the gravel lies. Most of this material, however, was undoubtedly deposited during the Pleistocene epoch of the Quaternary period, when moist conditions generally prevailed, glaciers occupied the region some distance to the north, and excessive precipitation and melting of the ice caused floods that brought down large boulders as well as smaller cobbles and pebbles. The coarser material was dropped close to the mountains, where steep stream gradients suddenly became gentle, and the waters spread out on the plains. Only the smaller pebbles and sand were carried out onto the plains and now form the stream terraces. High gravel terraces were probably also formed along the larger streams in late Tertiary time, but most of the gravel deposits that are preserved to-day and are mapped were accumulated in Pleistocene time.

RECENT SERIES

ALLUVIUM

Character and distribution.—More or less alluvium occurs in all the valleys and small ravines in the area, but only the deposits of considerable extent and thickness are mapped and will be described here. Within the mountain valleys it is difficult to separate the detrital material that is derived from weathered rock outcrops and has crept down the slopes from the stream-transported material in the valley bottoms, and therefore the alluvium has been mapped in only the broader valleys in the mountain area, those of Buchanan Valley and Opossum Creek.

Conewago Creek, which drains Buchanan Valley, passes through the deep, narrow gorge called The Narrows, which is cut in the hard rhyolite of the Big Hill-Bear Mountain ridge. As this hard rock is eroded much more slowly than the softer rocks of Buchanan Valley, it acts like a dam. The creek above this gorge, therefore, has been able to widen and deepen its valley in the softer rocks to such an extent that the stream has become sluggish and can not carry off the material brought into it by its tributaries. An alluvial bottom of considerable width has thus been formed just above The Narrows. Through The Narrows the grade is steep, the stream flowing on bedrock much of the way. Below The Narrows the grade becomes gentle again on the soft rocks of the Triassic, and the alluvial bottom is wider down to the next interruption to rapid erosion, the large diabase sill that crosses the stream's course near Newchester. From this point down the stream is deeply intrenched in large meanders, and the rocks are relatively resistant, so that the flood plain is narrow and the mappable alluvial deposits are discontinuous. Alluvial bottoms extend up the valleys of Beaverdam Creek and Opossum Creek, large branches of the Conewago. The wide, flat limestone valley of the upper part of South Branch of Conewago Creek is covered with fine alluvial silt containing chert and slate fragments, but it narrows to unmappable size to the north in the shale hills of the Triassic.

The valleys of Marsh Creek and Little Marsh Creek have almost continuous bottoms of alluvium which alternately widen and narrow as softer and harder strata are encountered. Rock Creek occupies a deep, narrow valley and has little alluvium. Middle Creek and Toms Creek, although their valleys are open, do not have mappable alluvium below the alluvial fans and terraces.

The alluvium of Marsh, Little Marsh, Conewago, and Opossum Creeks is composed of gravel derived from South Mountain rocks, chiefly rounded fragments of rhyolite, sandstone, and quartz in a matrix of sand, clay, and humus. The alluvium of South Branch of Conewago Creek is composed of fine sand with chert from the disintegrated limestone and fragments of quartz and slate from the slate hills to the southeast.

The alluvium in the stream bottoms is still being deposited, and most of it was accumulated by the streams under present conditions and therefore is of Recent age.

TRIASSIC IGNEOUS ROCKS

DIABASE

GENERAL FEATURES

Lithologic character.—The diabase of the larger bodies has a very different appearance from that of the dikes and thin sills, although they are practically identical in chemical composition. The rock of the larger bodies is coarse grained, granular, and composed dominantly of white or gray plagioclase and black pyroxene, with accessory quartz and magnetite and in places hypersthene, biotite, and olivine. The abundance of the dark minerals gives the rock a dark-gray hue.

Weathering.—The rock weathers readily by reason of the decomposition of its feldspar and pyroxene. It first bleaches to a gray or light-buff color at the surface and along joint planes, and then the decomposing and oxidizing minerals swell and cause the rock to flake off in thin sheets parallel to these surfaces. This flaking is aided and in some localities caused by daily and seasonal temperature changes of the rock and by the freezing of water in crevices. Following the tendency to cut corners, these thin sheets develop into curved plates and concentric layers, and the weathered rock soon takes on a rounded and spheroidal form. (See pls. 8, 9.) The boundary between altered and unaltered rock is generally very abrupt, the loosened weathered layer resting on perfectly sound though discolored rock or on rock only slightly weathered to a gray color. Where the loose layers do not fall away several concentric shells of weathered rock may inclose the sound rock. The weathered layer gradually disintegrates into buff granular sand, and the feldspar and pyroxene eventually alter to red clay in which numerous black crystals of magnetite sparkle. The magnetite is collected by the rivulets into black streaks in the soil and along the roads. The red clay makes a deep rich soil where not too rocky.

The dikes and thin sills are dark and dense throughout and are even finer grained at their contacts, some of the rock being so fine that its igneous character is not easily detected even with a hand lens. Some of the thin sills have a finely vesicular upper contact, where steam accumulated in bubbles in the upper part of the viscous mass. (See pl. 10.) These bubbles were caused by steam, either formed from water in the overlying shales or derived from the molten magma and accumulating at the upper surface of the intrusive sheet. Some of the contact surfaces of these thin sills also show polygonal cracking, the beginning of incipient columnar structure.

The dense diabase is very tough and weathers by disintegration into small spheroidal masses in rusty granular sand, which eventually alters to yellow clay. The spheroidal masses generally have a core of tough unaltered rock inclosed in concentric shells of partly disintegrated rusty material which readily fall into grains when disturbed. The clay soil is rich but is generally too rocky for cultivation, as the dense facies weathers more slowly than the coarse diabase. It is also eroded more slowly than the soft sandstone and shale of the Newark group, in which the dikes and sheets generally occur, so that it forms hills strewn with round diabase masses called "ironstone."

Mode of occurrence.—All the igneous rocks of Triassic age in the Fairfield and Gettysburg quadrangles with one exception are intrusive sills or dikes. (See fig. 8.) They occur

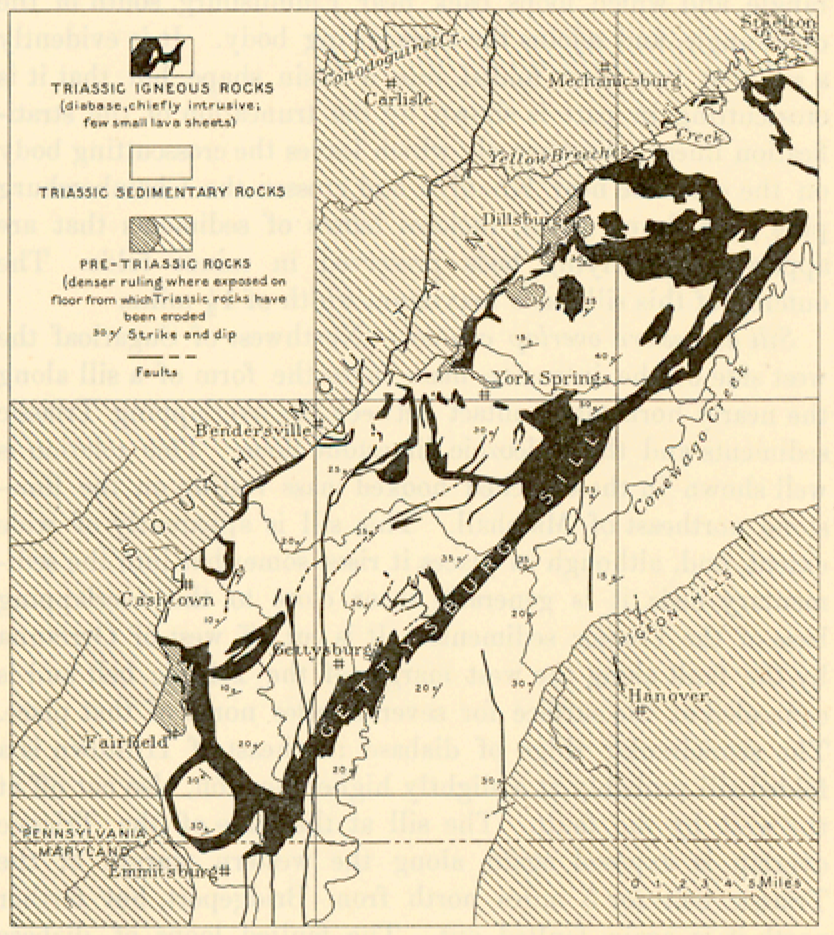


FIGURE 8.—Map showing the Gettysburg sill and associated intrusive masses of Triassic diabase

almost exclusively in the Triassic sediments, although one dike has been traced into the pre-Cambrian rocks in the northwest corner of the Gettysburg quadrangle.

In New Jersey and eastern Pennsylvania sheets of basalt that were formed by the cooling of molten lava that flowed out upon the surface are interbedded with the Triassic sediments. The sheets and dikes exposed in the Fairfield-Gettysburg area were formed of molten rock which probably came from the same source as the lava flows but which did not reach the surface, having cooled in the channels and crevices that it found or made in the sedimentary rocks. From the size of the

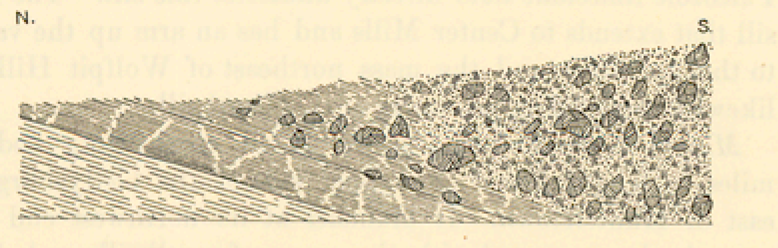


FIGURE 9.—Section of basalt lava flow in roadside cut half a mile south of Bendersville

Light-colored shale at left overlain by red shale and sandstone in which are scattered masses of decomposed vesicular basalt. (Details of photograph, pl. 11)

Gettysburg sill it seems probable that considerable of this molten material must also have reached the surface as lava. All such lava, except the small sheet south of Bendersville and possibly other masses to the northeast, has been removed by erosion. The inner of the two sheets shown on the map, exposed in the road just south of Bendersville, consists of a mixture of rounded masses or boulders of diabase in a red sandy matrix at the base overlain by fine-grained diabase that is badly decomposed but is in part finely amygdaloidal. (See pl. 11 and fig. 9.) It is believed to be a small lava flow.

Gettysburg sill.—The main body of diabase in the area is a large sill which crosses the Gettysburg quadrangle from its southwest to its northeast corner. It has a general thickness of about 1,800 feet and a width of outcrop of 1 mile, which widens at the northeast to $2\frac{1}{2}$ miles. The sill dips northwestward, with the inclosing strata, the inclination of its exposed upper surface being 20° in the Gettysburg Battlefield. For 5 to 8 miles through Newchester the outlines of the sill are straight and its width of outcrop is uniform, but toward the southwest the outlines become tortuous and the width increases. This change is not due to folding of the inclosing strata but apparently is largely caused by crosscutting of the intrusive body to higher horizons, as is shown on the geologic map by the higher position of the sill in the Gettysburg shale toward the southwest. The offsets of the sill near Rocky Grove School, east of Gettysburg, are apparently due to cross faulting. At the northeast, where the outcrop of the sill widens to $2\frac{1}{2}$ miles, the base of the sill remains at the same horizon and the upper surface apparently does the same, the widening being probably accomplished by the lifting of the covering beds higher where the sill is wider, and the strata on opposite sides of the crosscutting body southeast of Heidlersburg do not match but are offset.

Middle Creek crosscutting body.—Of the several crosscutting bodies which branch at right angles from the upper side of the Gettysburg sill the largest in the area is the one in Middle Creek valley, which extends northward as far as Orrtanna, terminating abruptly about 1 mile east of that place. It is about 1 mile thick throughout its length of 8 miles. Several sills branch from it at right angles between the sedimentary beds. One of the most interesting offshoots is the sill which forms McKee Knob, near the south border of the Fairfield quadrangle, and which loops back near Emmitsburg, south of the quadrangle, and rejoins the crosscutting body. It is evidently a sill that has been folded into a basin shape, but that it is crosscutting in part is shown by the truncation of the stratification lines. Another sill, which leaves the crosscutting body on the east side near Knoxlyn and crosses the Chambersburg pike near Seven Stars, incloses lenses of sediments that are apparently overlying beds preserved in minor folds. The outcrop of this sill has a maximum width of $1\frac{1}{2}$ miles.

Sill at western overlap contact.—Northwest of Sugarloaf the west side of the intrusive mass takes the form of a sill along the nearly horizontal contact between the overlapping Triassic sediments and the Paleozoic limestone floor. This relation is well shown in the detached hooked mass resting on the limestone northeast of Marshall. This sill is apparently of wide extent, and, although in places it rises somewhat into the sedimentary beds, it is generally at or close to the overlapping base of the Triassic sediments. It is cut off west of Orrtanna by the fault along the west margin of the Triassic belt and is concealed at the surface for several miles north of that place. The semicircular ridge of diabase northeast of Hilltown is a folded sill probably at a slightly higher horizon, also cut off at the west by the fault. The sill at the base of the Triassic overlap is exposed again along the western margin of the Triassic belt for 5 miles north from Bridgeport, but farther north it is again faulted out. The faulted loops of diabase east of Bendersville are apparently sills at slightly higher horizons, similar to the Hilltown sill. Most of the diabase masses north of Chestnut Hill are believed to be either exposures of this contact sill or to be closely connected with it. The evidence for this belief is not clear in the Gettysburg quadrangle, but to the north in the Carlisle quadrangle it is more convincing. For 3 miles along the creek valley northwest of York Springs, in the Carlisle quadrangle, the Paleozoic limestone is exposed beneath the horizontal overlapping Triassic conglomerate, but directly to the north the diabase sill again follows the Triassic contact. It is believed that the diabase masses along the north edge of the Gettysburg quadrangle are exposures of the sill at the same contact and that the Paleozoic limestone floor directly underlies this sill. The long sill that extends to Center Mills and has an arm up the valley to the northeast, and the mass northeast of Wolfpit Hill are likewise regarded as exposures of this basal sill.

Minor crosscutting bodies.—A small crosscutting body 2 miles in length leaves the upper side of the Gettysburg sill east of Hunterstown. It branches at its northwest end and may also be connected with the group of small sills and dikes southwest of Hunterstown. Another long, slender body leaves the Gettysburg sill at its wider part near Round Hill and extends across the bedding of the sedimentary rocks for 4 miles, sending off irregular dikes and thin sheets on both sides. North of Heidlersburg it spreads out to a mile in width and then contracts to a narrower body that runs north into the Carlisle quadrangle.

The Chestnut Hill igneous mass is a diabase sheet at a higher horizon, apparently fed by a dike that joins it on the west. Its present shape suggests that it was of small lateral extent and relatively thick—that is, of laccolithic habit—and bowed up the covering strata, but as none of the cover is preserved this suggestion can not be positively confirmed.

At Bermudian Churches the Gettysburg sill widens locally to 4 miles by crosscutting and does not seem to have lifted the covering strata higher than elsewhere. The small isolated body in the Bermudian Creek valley is probably a crosscutting offshoot from this intrusive mass that has been exposed by erosion only at this place. The small inclosed mass of diabase to the south is probably a thin sill at a higher horizon than the Gettysburg sill, folded into a basin shape.

Dikes and thin sills.—Numerous dikes and sills so thin that they appear on the map as single lines of color occur throughout the intruded areas. The most prominent dike is the one which forms Seminary Ridge and Oak Ridge, west of Gettysburg, and which runs through Goldenville and east of Biglerville and Guernsey into the Chestnut Hill body. It is 92 feet thick at the railroad cut west of Gettysburg and dips 50° E. (See fig. 10.) It terminates at the south in the Gettysburg sill.

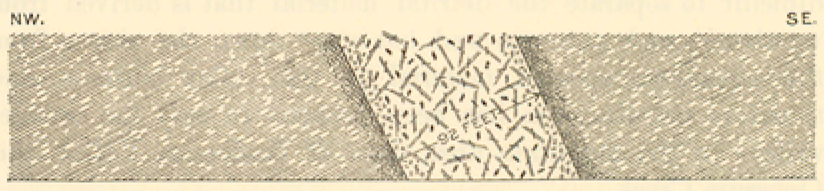


FIGURE 10.—Section of diabase dike of Seminary Ridge exposed in railroad cut half a mile west of Gettysburg

Diabase is crystalline in middle and fine grained and crumbly at contact. Soft red shale is baked at contact to hard black dense rock

Another dike, which extends many miles into Maryland, enters the Fairfield quadrangle at its southeast corner and forms a prominent ridge that is followed by West Confederate Avenue for some distance. As it is traceable across the Gettysburg sill, it was intruded somewhat later than that body. It is poorly exposed in the Western Maryland Railway cut west of Gettysburg, where it appears to dip at a low angle to the west. It terminates at the north in a small forked mass northeast of Seven Stars. Southwest of Hunterstown there is a more or less rectangular network of dikes and sills, where the molten material apparently followed joints and irregular fractures in a badly shattered zone.

Many single dikes or sills occur in the more intricately intruded area in the northern part of the Gettysburg quadrangle. Nearly all of them can be traced to some larger body with which they connect either as attenuated ends of narrow branches or as abrupt offshoots from the main body. East of Gettysburg a thin sill was observed a few feet above the large Gettysburg sill, and south of Wolf Hill two other such thin sills occur just below the larger sill.

Only a few dikes were observed below the Gettysburg sill. A dike leaves the lower side of the sill near Welcome School and has been traced southward about 3 miles. Another having the same general direction but lying to the east has been followed south from Conewago Creek for 3 miles near the east margin of the Gettysburg quadrangle. It is probably a continuation of the dike which has the same general direction and whose north end just enters the quadrangle north of Midway. The longest dike in this part of the area extends from Cedar Ridge through Square Corner to the south edge of the quadrangle and across the Paleozoic limestone and Cambrian schist into Maryland.

General relations of the intrusive masses.—A study of the intrusive bodies in this region leads to the conclusion that the general form of the main body is that of a great trough-shaped mass, the eastern edge of which comes to the surface as a sill between sedimentary strata—the Gettysburg sill—and the western edge as a sill along the contact of the gently overlapping Triassic sediments on older rocks, exposed only in places. (See fig. 8.) The south end comes to the surface as the large crosscutting body southeast of Fairfield; the north end as the thick crosscutting mass east of Dillsburg, in the Carlisle quadrangle. The bottom of the trough is joined by a great crosscutting body that fills the vent up which the intrusive mass ascended. (See sections E, F, fig. 6.) The diabase may not be continuous throughout the trough, for the sill at the exposed basal contact is very thin if not absent in places.

Source of the intrusion.—It is believed by the writer that the igneous magma came into the Triassic sedimentary rocks from the depths of the earth through fissures in the bottom of the basin in which the sediments were deposited. The depression of the earth's surface into long basins in this and other parts of the Appalachian region in which the Triassic sediments were deposited indicates that the deep-seated rocks beneath these areas were deficient in strength, possibly owing to a lack of pressure or support from the surrounding rocks during internal readjustments within the earth, and that the unsupported rocks yielded to gravity and sank. The sinking of the basin was accomplished in part by faulting, the west side of the block sinking along a fault near the west edge of the basin while sedimentation was going on. This fault plane offered a channel through which molten rock could escape from the interior. How the rock became molten is not known, but possibly the reduced pressure in the underlying deep-seated rocks, which led to the sinking of the basin, caused some of them to melt at the normal heat at that depth in the earth, which, however, was not great enough to melt them under the pressure that normally exists at that depth. Or it may be that the deep-seated rock melted when the internal pressure was reduced and that the covering rock broke and blocks of it, settling on one side, sank into the molten matter, which was thereby forced upward into the breaks. The molten rock found an outlet through the faulted floor of the Triassic basin and entered the Triassic sediments chiefly along two channels, one at the western basal contact of the Triassic sediments and the other between sedimentary layers, forming the Gettysburg sill, as illustrated in Figure 6. Numerous small arms of the larger masses entered the sedimentary beds as crosscutting bodies, dikes, and minor sills.

Age.—Some of the diabase masses cut the youngest beds of the Newark group in the Fairfield and Gettysburg quadrangles and are therefore younger than these beds. Some are cut off at the western border of the Triassic basin by faults which drop both the sedimentary and igneous rocks, so they are older than the crustal movement that closely followed the deposition of the Newark sediments. Farther east in Pennsylvania and in New Jersey the intrusive diabase is accompanied by basalt flows, which are interstratified with the upper beds of the Newark group, and one such lava bed apparently occurs at Bendersville, in the Fairfield quadrangle. These lavas and the larger bodies of intrusive rock are therefore of late Triassic age, and some dikes are even younger than these main intrusive masses, because they distinctly cut across the Gettysburg sill, and represent a still later eruption of the molten magma from which the larger bodies came.

Metamorphism of the Triassic sedimentary rocks. — The intrusive diabase altered the sedimentary rocks which it invaded by increasing their hardness and changing their color and chemical composition. These changes were produced by the heat of the diabase in conjunction with the water that saturated the country rock and became heated by the injected mass, and also by the introduction of certain minerals by hot solutions that accompanied the intrusions. The most noticeable effect on the sedimentary rocks is their so-called "baking" or hardening immediately adjacent to the diabase. The hardened altered sandstone and shale are much more resistant to erosion than the softer unaltered beds and form ridges along the borders of the intrusive masses, some of which stand even higher than the igneous rocks.

Soft argillaceous shale was changed to hard argillite or hornfels and to brittle porcelanite. In the process bright-red shale was changed first to dull red and then to dark purple and black, through deoxidation of the red ferric oxide coloring matter by heating in the presence of organic matter or some other reducing agent. Some beds became bleached to light buff or white, possibly by the distillation of contained dark carbonaceous matter. Some of the altered shale is speckled with dark or light round bodies or spots, which are segregations of various minerals. The light spots are generally composed, in part at least, of quartz, opal, or sericite. The dark spots are due to the presence of magnetite, epidote, or chlorite. Solid round epidote concretions closely resembling spherulites mark some layers. (See pl. 23.) J. V. Lewis, who made the microscopic examination of the metamorphosed rocks of this area, reports not only the presence of these metamorphic minerals in the altered shale but also abundant biotite and feldspar and less commonly calcite, tourmaline, hematite, hornblende, augite, and wollastonite. Most of these minerals were probably produced by the action of hot water on the original content of the shale, but the large amount of magnetite present in these and other altered sedimentary rocks of the area must have been in greater part introduced directly by the solutions that accompanied the intruding mass.

The metamorphic effect of the larger diabase masses in places penetrated the wall rock about 100 feet, but the extreme hardening and altering of color is limited to 20 or 30 feet. Adjacent to smaller intrusive masses the effect was less, and the thin dikes and sheets produced very little alteration. The dike in the railroad cut west of Gettysburg, which is 92 feet thick, has at its contact only an inch or two of black dense altered shale, which is readily mistaken for the fine-grained chilled surface of the diabase. (See fig. 10.)

Sandstone was generally not so markedly affected by intrusion. It was somewhat hardened by being more compactly cemented, the clayey matter in the arkosic sand being changed into a hardened cement and to new minerals. Certain sandstones, presumably nearly pure quartzose sand, in the vicinity of Cashtown and in the southern part of the adjacent Carlisle quadrangle have been altered to light-gray vitreous quartzite that is somewhat porous from the absence of cement, the quartz grains having grown into more or less interlocked crystals. The rock breaks readily into small angular fragments which strew the fields, so that ledges of the rock are not seen.

The limestone conglomerate and calcareous beds at the western edge of the Triassic sedimentary rocks, where penetrated by the diabase, exhibit marked metamorphism. In many places small masses of lime-iron garnet have been produced by the addition of iron to the calcareous beds. Garnet is plentiful in most of the magnetite prospects in the area, and in some places, as northwest of Sugarloaf, the underlying Paleozoic limestone has been changed at the contact to this mineral. The fields in such places are filled with masses of dirty-yellow porous heavy granular rock composed wholly of garnet.

Magnetite, an original constituent of the diabase, has been locally introduced into the sedimentary rocks in large quantities. In places in the altered slaty rocks it is intergrown with garnet and calcite, forming small aggregates which presumably have replaced limestone concretions, limestone pebbles, or irregular calcareous layers. In favorable places magnetite has been segregated in larger quantities and forms bodies of iron ore. Such deposits have been mined east of Hilltown and northeast of Fairfield. Some specular hematite and iron pyrite occur with the magnetite in places. The iron in these larger deposits no doubt came directly from solutions that accompanied the intruding diabase, replacing the limestone little by little until the replacement was complete.

Some of the limestone beds in the Ledger formation, which directly underlie Triassic sandstone in the southeastern part of the Gettysburg quadrangle have been altered to fine-grained pink, purple, or red marble. Such altered rock is finely shown in the limestone quarries near Irishtown. Many of the pebbles in the Triassic limestone conglomerate have been similarly changed. The colors were apparently introduced by circulating waters that carried the stain from the overlying red rocks into the pores and cracks of the limestone. The limestone seems to have been made more crystalline at the same time, a result which might have been facilitated if the circulating waters were heated by the diabase intrusion.

PETROGRAPHY

By J. Volney Lewis

General character.—The diabase of the larger sills and crosscutting bodies has a very different appearance, in the main, from that of the dikes and thin sills, although they are undoubtedly derived from the same original magma. Indeed, rocks of some of the most strongly contrasted types are obviously parts of one continuous mass, and all are doubtless united in a similar manner at no great depth. The diabase of the larger bodies has as a rule a coarse grain and a color ranging from light gray and pink to dark gray, and some of it is quarried and marketed as "granite." That of the dikes and thin sills, on the other hand, has a fine-grained to aphanitic texture and is nearly black.

The most abundant constituents of the diabase are greenish-black pyroxene and white or grayish plagioclase. The pyroxene commonly preponderates, but in many places the two minerals are approximately equal and in some places the feldspar is in excess. Crystals and irregular grains of magnetite and minute crystals of apatite are rather plentiful, and there is generally a little quartz and orthoclase. The darker varieties of the rock contain in places much hypersthene or olivine, or both; in the lighter-colored facies, on the other hand, quartz and orthoclase are abundant—as a rule micrographically intergrown in greater part. Here and there are much smaller amounts of biotite and, far less commonly, titanite. The pyroxene is rather commonly altered in part to uralitic amphibole, serpentine, or chlorite, with, as a rule, more or less granular magnetite. A corresponding partial alteration of the feldspar has given rise to fine scaly, apparently sericitic aggregates and, less commonly, to kaolin. In places epidote is also an abundant secondary mineral.

Texture.—All the diabase masses are finer grained at their borders, where the magma was chilled by contact with the inclosing rocks, but in the larger masses even these parts are generally not so dense and dark as the rock of the dikes and thin sills. The rock of the small masses is dense throughout, and some of it is so fine and homogeneous in appearance that its igneous character is not easy to detect, even with a hand lens, although it may generally be inferred from the greater weight of the rock in comparison with the associated dense black baked shale.

Rock having the typical diabasic texture consists of elongated lath shaped crystals of plagioclase lying in all directions, with pyroxene and other minerals occupying the interstitial spaces. Where the pyroxene forms larger continuous areas in which the plagioclase crystals are embedded the texture is called ophitic. In the coarser varieties of the rock the individual minerals may be recognized, and the felted or matted arrangement of the elongated feldspar crystals is readily seen in hand specimens. In the fine-grained and aphanitic varieties, on the other hand, the texture is visible only with the aid of the microscope, and the thinner dikes and sills show all gradations to typical basalt with glassy groundmass.

Order of crystallization.—From the prevailing diabasic texture of the rock it is evident that the crystallization of the plagioclase was generally completed before that of the pyroxene. To this general rule there are, however, two exceptions: (1) In some of the coarse-grained feldspathic and quartzose facies of the rock, in which orthoclase is the chief feldspar and plagioclase is much less abundant, the pyroxene has a well-developed prismatic form and has obviously preceded the bulk of the feldspar in crystallization. (2) In the fine-grained contact facies of the larger masses and in the dense black dikes and thin sills, there is a general occurrence of pyroxene phenocrysts, with only here and there a large feldspar crystal, which indicates that the pyroxene crystallized before the feldspar.

Apatite and magnetite, as shown by their crystalline form and their indifference to the other minerals, were among the first to crystallize; and here and there an inclusion of apatite in magnetite shows that the apatite crystallized first. Olivine, where it occurs, preceded both the pyroxene and the feldspars, in both of which it forms inclusions. Orthoclase and quartz were the last to crystallize, first in micrographic intergrowth, where this was formed, and then as separate grains of the two minerals, with quartz alone filling the last remaining interstices.

Varieties.—Differentiation within the diabase while still in liquid condition has given rise to several well-defined varieties of rock in which the minerals occur in widely differing proportions. Thus, designating as (1) normal diabase the most common pyroxene-feldspar aggregate described above, we may name additional varieties as follows: (2) feldspathic diabase, or anorthosite, consisting chiefly of plagioclase; (3) quartz diabase, with abundant quartz, chiefly in micrographic intergrowth with orthoclase; (4) micropegmatite, consisting mainly of an intergrowth of quartz and orthoclase; (5) aplite, essentially a dense granular quartz-orthoclase rock; (6) hypersthene diabase, with much hypersthene replacing in part the common monoclinic pyroxene; (7) olivine diabase, with abundant olivine; (8) basaltic diabase, or basalt, the dense black facies, in places vesicular and having a glassy groundmass; (9) olivine basalt, the dense black variety with abundant olivine. These varieties have not been separately mapped. Petrographic details have been given in a previous paper by the writer.[7]

Chemical composition.—Several types of Triassic diabase from many localities in the Atlantic States have been analyzed, and some of the analyses are given in the following table:

[7] Lewis, J. V., Geol. Soc. America Bull., vol. 27, pp. 630-644, 1916.

Analyses of Triassic diabase

	1	2	3	4	5
SiO_2	46.87	49.02	55.31	60.05	71.60
Al_2O_3	13.36	10.14	13.64	11.88	13.16
Fe_2O_3	9.79	1.54	.52	3.22	1.28
FeO	2.71	10.46	8.49	10.21	.38
MgO	4.35	17.25	12.73	.85	2.12
CaO	14.70	8.29	12.41	4.76	3.76
Na_2O	4.64	1.59	1.40	4.04	5.92
K_2O	2.01	.40	.32	2.10	.70
H_2O+		.59		.66	
H_2O-		.16		.21	
TiO_2	1.98	.99	Trace.	1.74	.34
P_2O_5		.11	Trace.	.52	Trace.
MnO		.16	Trace.	.28	.03
	100.41	100.70	100.82	100.52	99.29
Specific gravity		3.152		2.872	

1. Normal diabase, Birdsboro, near Norristown, Pa. Analyst, H. Fleck (U. S. Geol. Survey Nineteenth Ann. Rept., pt. 6 (continued), p. 222, 1898).
2. Olivine diabase, the Palisades, Englewood Cliffs, N. J. Analyst, R. B. Gage (Geol. Survey New Jersey Ann. Rept. for 1907, p. 121, 1908).
3. Hypersthene diabase, The Twins, Culpeper County, Va. Analyst, W. G. Brown (Geol. Soc. America Bull., vol. 2, p. 346, 1898).
4. Quartz diabase, Pennsylvania Railroad tunnel through the Palisades, 400 feet from the west portal, Homestead, N. J. Analyst, R. B. Gage (op. cit., p. 121).
5. Aplite, Goose Creek, Va. Analyst, E. V. Shannon (U. S. Nat. Mus. Proc., vol. 66, p. 28, 1924).

Mineral composition.—The proportions of the mineral constituents in certain facies of the Triassic diabase have been determined by the Rosiwal method, with the results that are given in the following table. No measurements have been made upon aplite and micropegmatite, some specimens of which are composed almost exclusively of quartz and orthoclase in approximately equal amounts.

Mineral composition of certain facies of diabase

	1	2	3
Quartz			19
Feldspar	37	18	44
Pyroxene	59	58	27
Biotite		1	3
Olivine	1	20	
Magnetite	3	3	7

1. Normal diabase, the Palisades, Englewood Cliffs, N. J.
2. Olivine diabase, the Palisades, horseshoe curve of trolley line, Edgewater, N. J.
3. Quartz diabase, Pennsylvania Railroad tunnel through the Palisades, 400 feet from west portal, Homestead, N. J.

GEOLOGIC STRUCTURE

STRUCTURAL RELATION TO THE APPALACHIAN HIGHLANDS

The structural features in the Fairfield-Gettysburg area are similar to those that prevail throughout the Appalachian Highlands. They comprise chiefly elongated folds that trend northeastward, parallel to the mountain system. Individual folds do not extend the whole length of the region; they gradually diminish in intensity, die out, and are replaced by others. The intensity of the folding increases from northwest to southeast across the region. In the western province, the Appalachian Plateaus, the folds are gentle and symmetrical, and the dip is generally less than 10° and decreases toward the west. The rocks have not been altered by the folding and compression, shales being free from cleavage fracture and interbedded coals having attained only the bituminous stage.

In the middle province, the Appalachian Valley and Ridges, the folding is more intense. Dips are generally 30° or more, and in many parts of the province the strata are now vertical. Most of the folds are unsymmetrical, the northwest sides of the anticlines being steeper and shorter than the southeast sides, and many of the folds are overturned, so that the beds on the northwest limbs of the anticlines dip to the southeast but at greater angles than those on the southeast limbs. The crest of such a compressed and overturned anticline is likely to be broken, so that the beds on the southeast limb are pushed over those on the northwest limb in the form of a thrust fault. The displacement along many of these fault planes is very great, in places being measurable in miles. The folds in this province are likewise of considerable magnitude, attaining 5 miles or more in height if theoretically restored. The larger folds are not simple units but are composed of numerous smaller folds side by side, and these in turn have still smaller folds on them, down to minute wrinkles, all trending in the same general direction.

The rocks in the Appalachian Valley and Ridges province have undergone a greater alteration from compression during folding than those of the Appalachian Plateaus. The sandstones and limestones are much jointed and hardened. Toward the eastern margin of the province cleavage is developed to a moderate degree in the limestone, and along thrust fault zones the rocks are sheared and recrystallized into schists. The shales are more crumpled than the inclosing harder rocks, and cleavage is developed to so great a degree that the bedding is in places obliterated. The coal that occurs in this province has attained the anthracite stage.

In the Blue Ridge and Piedmont provinces, east of the Appalachian Valley, the compression reached a maximum, and cleavage, schistosity, and recrystallization of the particles of the rocks have obliterated much of the original texture and to some extent the original structure. Shale has been altered to slate, phyllite, or schist, limestone to marble, sandstone to quartzite, and igneous rocks to gneiss and schist. Many of the finer-grained rocks and even the marble in these provinces are so intricately crumpled and folded that they appear to have been made plastic by the great pressure and accompanying heat.

GENERAL STRUCTURE OF THE FAIRFIELD-GETTYSBURG DISTRICT

The Fairfield-Gettysburg district comprises three structural divisions—South Mountain, the Triassic area, and the Paleozoic area east of the Triassic—each marked by somewhat different types of structure. South Mountain is a region of intense compression with closely compressed longitudinal folds and numerous thrust faults. The Triassic sedimentary rocks are in general unfolded, have gentle dips, and are broken and dislocated by normal faults along their western margin. The Paleozoic rocks, east of the Triassic, including those of the schist hills in the southeast corner of the district, are closely folded and faulted, like the rocks of South Mountain, but in addition have a schistose structure due to more intense compression and metamorphism, so that the detail of the folded structure is almost obliterated.

SOUTH MOUNTAIN

General character.—South Mountain is a great anticlinorium defined on the west by steep westerly dips toward the limestone valley and on the east by a series of normal faults along the margin of the Triassic rocks. (See fig. 11.) It comprises three or four major anticlines, in some of which the pre-Cambrian rocks are exposed, and corresponding synclines, which inclose Cambrian sandstones and some limestone. The pre-Cambrian rocks form the surface of about half of the South Mountain area in these quadrangles. Cambrian rocks occupy all the western part of the mountain area and are infolded in several bands in the eastern part. An east-west cross fault along the valleys of Conococheague, Carbaugh, and Marsh Creeks divides the mountain area into two structural parts.

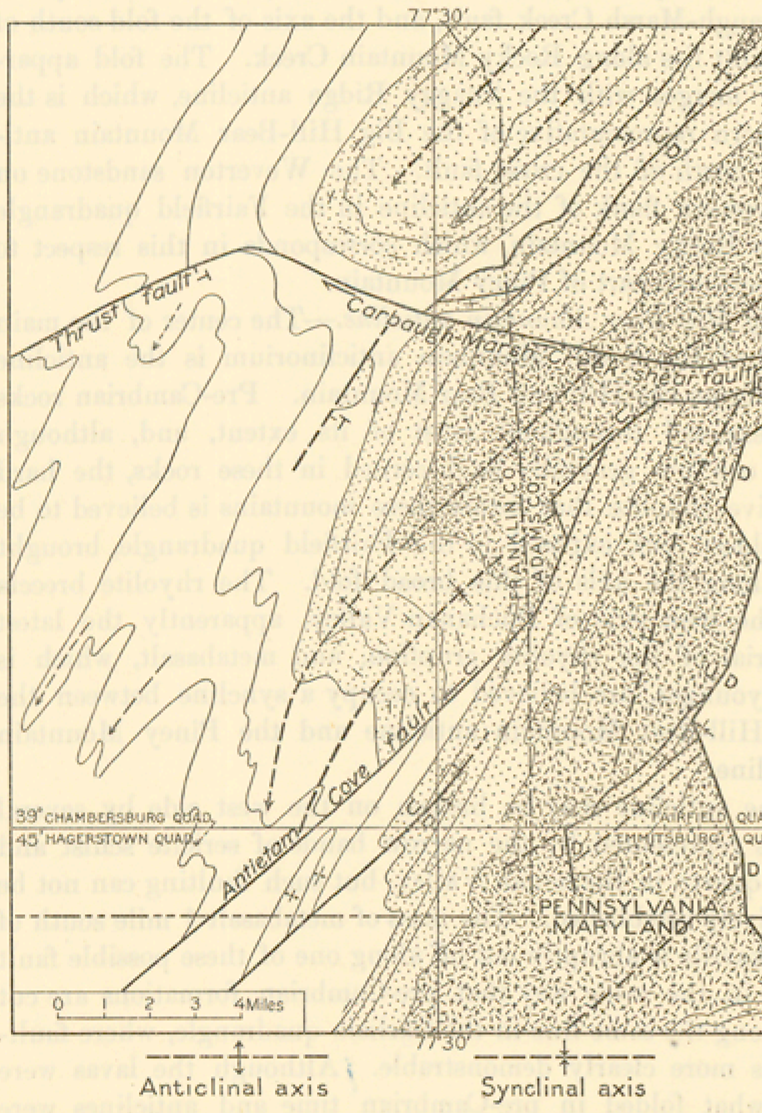


FIGURE 11.—Sketch map showing major faults and structural axes in South Mountain in the Fairfield quadrangle and adjacent region

The block between the Carbaugh-Marsh Creek and Antietam Cove faults was apparently forced southwestward as a wedge sheared along diverging breaks diagonal to the direction of pressure, as explained on pages 14-15. Dot pattern represents Cambrian quartzose rocks; hachure pattern, pre-Cambrian rocks. Lines represent formation boundaries

Big Flat Ridge anticline.—The high mountains in the extreme northwest corner of the Fairfield quadrangle are included in the Big Flat Ridge anticline, which trends northeastward and extends from the adjacent part of the Chambersburg quadrangle far beyond the northern boundary of the Fairfield quadrangle. The uppermost Cambrian sandstones, which rise steeply on the west limb of the fold from under the limestones of the valley in the extreme corner of the quadrangle, descend less steeply on the east limb along the foot of the discontinuous ridge extending from Quarry Hill to Rocky Knob. The anticline is broad-topped, owing in part to the fact that it has a double axis. The elevation along the eastern axis was sufficient to expose the Weverton sandstone at the surface, but the western part of the fold is very gently rolling at the crest. The anticline plunges steeply southwestward just beyond the edge of the quadrangle, where the sandstones are carried abruptly beneath the limestones of Cumberland Valley around the end of the fold. (See fig. 13.)

Hosack syncline.—East of the Big Flat Ridge anticline a closely compressed syncline incloses Tomstown dolomite, and patches of sandstone on its east limb are remnants of overturned Antietam sandstone, cut off by an overthrust fault. The old Hosack Run iron mine was located in this syncline, and it will be called the Hosack syncline. The syncline rises to the north and ends against the fault on the top of Big Flat Ridge.

Wildcat Hill anticline.— An anticline bounded on both sides by faults extends from Wildcat Hill northeastward far beyond the edge of the Fairfield quadrangle. The Loudoun formation is exposed along the axis on the north side of Wildcat Hill and in the upper valleys of Conococheague and Mountain Creeks, and pre-Cambrian rocks appear along the axis at the north edge of the quadrangle. The west limb of the anticline is broken, and the Montalto quartzite is thrust northwestward, concealing much of the east limb of the Hosack syncline. The east limb of the anticline is cut off by a fault, which swings westward and cuts off both limbs southwest of Wildcat Hill.

Piney Mountain anticline and Mountain Creek syncline.—The anticline that gives rise to Piney Mountain is part of the main uplift of South Mountain. Its axis lies a little east of the crest in the northern part of the mountain but coincides with the crest in the southern part. A minor fold is shown by the attitude of the Weverton sandstone and Loudoun formation in the small outlying ridge on the east side of the extreme southern part of Piney Mountain. Pre-Cambrian rocks are exposed at the crest of the fold east of Piney Mountain. The west limb of the anticline and the Mountain Creek syncline, to the west, are cut off throughout most of the area by a normal fault, but at the north border of the quadrangle the Mountain Creek syncline, inclosing Antietam sandstone and Tomstown dolomite, is preserved, dropped down opposite the Loudoun formation of the adjacent Wildcat Hill anticline. Toward the southwest the Mountain Creek syncline is represented by the east-west band of Antietam sandstone and Tomstown dolomite between diverging faults west of Graefenburg Hill.

The Piney Mountain anticline is offset to the west by the Carbaugh-Marsh Creek fault, and the axis of the fold south of the fault lies along Rocky Mountain Creek. The fold apparently merges with the Snaggy Ridge anticline, which is the southern representative of the Big Hill-Bear Mountain anticline north of the cross fault. The Weverton sandstone on the western flank of the anticline in the Fairfield quadrangle forms Rocky Mountain, which corresponds in this respect to the northern part of Piney Mountain.

Big Hill-Bear Mountain anticline.—The center of the main uplift of the South Mountain anticlinorium is the anticline that forms Big Hill and Bear Mountain. Pre-Cambrian rocks are exposed throughout most of its extent, and, although dips can not generally be discerned in these rocks, the hard massive rhyolite that forms these mountains is believed to be the oldest rock exposed in the Fairfield quadrangle, brought up along the axis of this broad fold. The rhyolite breccia on the west side of Buchanan Valley, apparently the latest material of the rhyolite eruption, and metabasalt, which is still younger, are believed to occupy a syncline between the Big Hill-Bear Mountain anticline and the Piney Mountain anticline.

The anticline may be broken on the west side by several faults represented by the narrow bands of sericite schist and vein quartz in Buchanan Valley, but such faulting can not be positively established. The mass of metabasalt 1 mile south of Wenksville is abruptly cut off along one of these possible fault lines, in the same way that pre-Cambrian formations are cut off along the same line in the Carlisle quadrangle, where faulting is more clearly demonstrable. Although the lavas were somewhat folded in pre-Cambrian time and anticlines were worn down before the Cambrian sediments were deposited upon them, the Big Hill-Bear Mountain anticline and associated syncline conform with the structure in the Cambrian rocks and were undoubtedly formed during the later stage of folding.

Snaggy Ridge and Buzzard Peak anticlines.—The massive rhyolite of Big Hill, in the axis of the fold, is offset by the Carbaugh-Marsh Creek cross fault to Mount Newman and Snaggy Ridge. This fold, called the Snaggy Ridge anticline, passes out of the Fairfield quadrangle west of Snowy Mountain. East of Snaggy Ridge the structure of the pre-Cambrian rocks is probably synclinal, inclosing metabasalt overlying the rhyolite, but another anticline is indicated by the rise of the pre-Cambrian rocks and the southward swing of the Cambrian quartzite at Buzzard Peak. This fold may be called the Buzzard Peak anticline.

Antietam Cove syncline and fault.—Antietam Cove is formed by Tomstown dolomite inclosed in a syncline. A great fault that cuts diagonally across the syncline brings the limestone successively against the truncated ends of the Antietam sandstone, Harpers schist and Montalto quartzite member, Weverton sandstone, and Loudoun formation. The abrupt termination of the ridges formed of these quartzites produces one of the most marked offsets in the mountain front in this region. (See fig. 12.) North of the cove the fault follows the strike of the Montalto quartzite, which is faulted against the pre-Cambrian volcanic rocks to the west. At the north end of Green Ridge the fault swings east and passes into the pre-Cambrian rocks. The Antietam Cove fault is difficult of explanation. From a casual inspection the relations seem to be that of a normal fault with the downthrow on the east. This suggestion, however, does not take account of the deep syncline inclosing Tomstown dolomite in Antietam Cove. Another explanation might be that it is a broken anticline of Cambrian quartzites overthrust from the northwest onto the limestone syncline, but this is not likely, because all known folds in this part of the Appalachian region are overturned

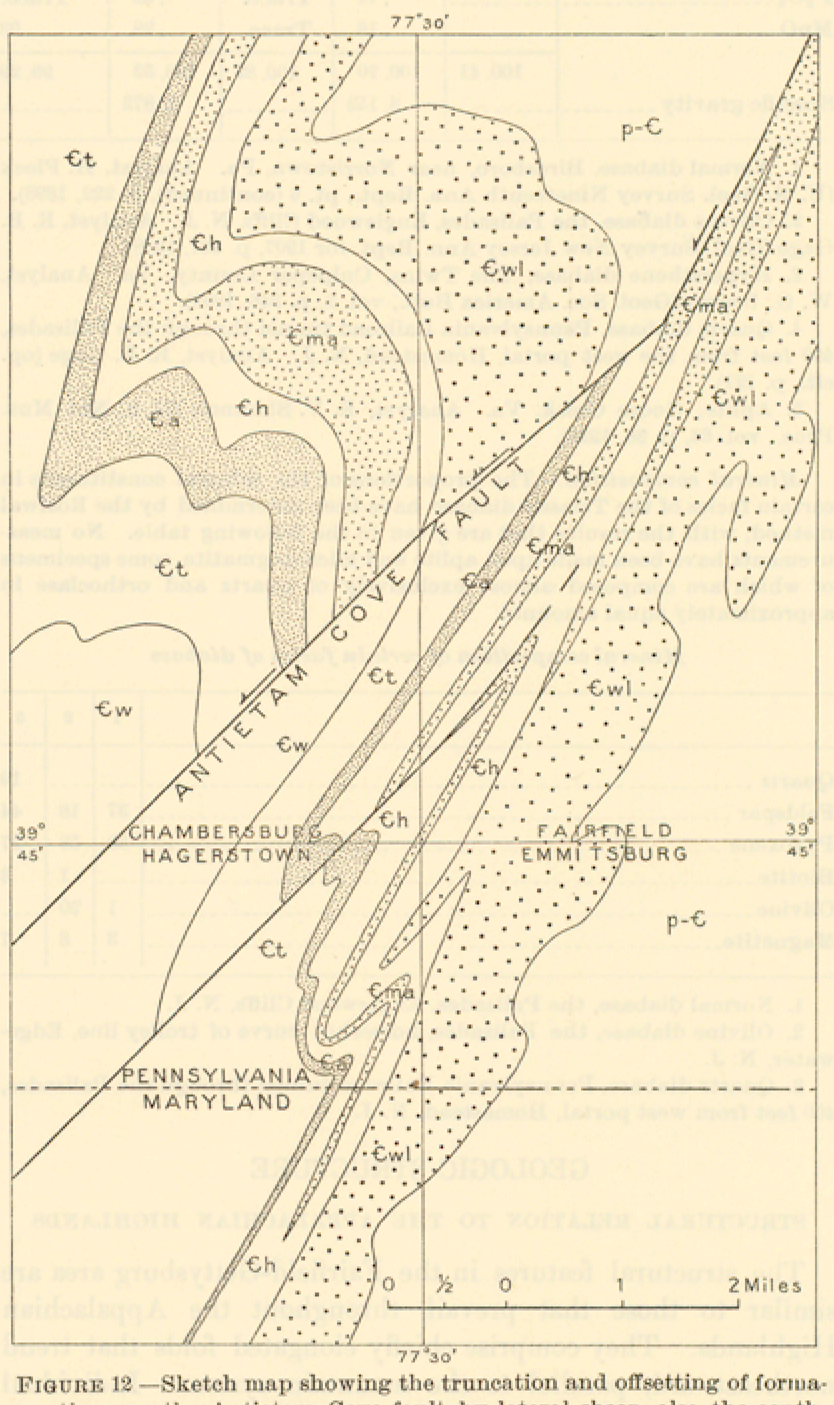


FIGURE 12.—Sketch map showing the truncation and offsetting of formations on the Antietam Cove fault by lateral shear, also the southward thinning of the Montalto quartzite member of the Harpers schist and the Antietam sandstone

€w, Waynesboro formation; €t, Tomstown dolomite; €a, Antietam sandstone; €h, Harpers schist; €ma, Montalto quartzite member of Harpers schist; €wl, Weverton and Loudoun formations; p-€, pre-Cambrian rocks

and overthrust to the northwest. The most plausible conclusion is that the fault is probably a diagonal shear across the beds on a nearly vertical plane, the Snowy Mountain block having moved southwestward and upward, in a manner similar to the movement on the Carbaugh-Marsh Creek shear fault on the north side of the block, described below. Such displacement might have resulted from the general compression from the southeast, the forces acting on the sides of a wedge-shaped block whose acute angle pointed eastward. (See fig. 11.) The sharp Buzzard Peak anticline and the compressed west limb of the Antietam Cove syncline would thus be obliterated or sheared off in the angle.

Green Ridge anticline.—An anticlinal axis lies along the east side of Green Ridge and passes through the saddle west of Kepner Knob and along the Devils Racecourse. The quartzite forming Virginia Rock lies practically horizontal on the top of the fold, and Kepner Knob and Monterey Peak, just east of the Devils Racecourse, in the Emmitsburg quadrangle, lie in a small syncline east of the axis. Pine Mountain is formed by another small syncline farther east. On the west flank of the Green Ridge anticline the Cambrian quartzites descend under the limestone of Antietam Cove but are cut off diagonally by the Antietam Cove fault north of the cove. A minor faulted fold on this flank of the anticline doubles back the Montalto quartzite at the Waynesboro reservoir, just west of the Fairfield quadrangle.

Rupp Hill anticline.—The massive rhyolite porphyry that forms a line of high knobs near the east edge of South Mountain, of which Rupp Hill is one of the most prominent, is apparently brought up on an anticline similar to the Big Hill-Bear Mountain rhyolite mass. The metabasalt bands on its flanks are apparently thin basalt flows interbedded with the upper rhyolite flows and mark synclines.

Jacks Mountain syncline.—Jacks Mountain is formed by a syncline of Cambrian quartzite which plunges northeastward. The Montalto quartzite and possibly the Antietam sandstone and Tomstown dolomite are inclosed in the syncline at Maria Furnace. The syncline is cut off on the northwest by two faults. The western one is apparently an overthrust fault whereby the syncline was thrust westward against the Rupp Hill anticline. The plane of the overthrust has a low dip to the east, as is finely shown in the partly excavated entrance to a tunnel of the old "tapeworm" railroad through a small spur about 1 mile south of Iron Springs. The smoothed and striated rhyolite floor of the fault dips 40° SE., and remnants of the Cambrian quartzite which is overthrust on it are shown in Plate 16. As few fault planes are exposed to view in this region, this artificial exposure is of unusual interest in observing the nature of some of the faults of the area.

The southeastern fault is nearly parallel to the northwestern one and cuts diagonally through the syncline south of Maria Furnace. It cuts off the Weverton sandstone of Jacks Mountain and of Tunnel Hill, at the south edge of the quadrangle, and may be seen in the tunnel on the Western Maryland Railway. It is apparently a normal fault.

Carbaugh-Marsh Creek shear fault.—The cross fault that follows the transverse valley (pl. 19) and low divide near Newman School, here called the Carbaugh-Marsh Creek fault, is a shear—that is, it cuts the rocks at right angles to their strike—is nearly vertical, and offsets the formations by a lateral displacement of about 2 miles. It is abruptly terminated on the east by the later normal fault along the border of Triassic rocks. Toward the west it passes into the Chambersburg quadrangle and connects with the thrust fault that runs southwest through Aqua. (See fig. 11.) Along Conococheague Creek in the Chambersburg quadrangle it is concealed by gravel deposits, and these relations were not yet worked out when the Mercersburg-Chambersburg folio was published, so the cross fault was not shown on the maps of that folio. The nature and cause of this fault, as well as of the other complicated structural features in the area, may be more clearly understood by a review of the processes by which the structural features were produced.

Mode of production of structure.—The folding and faulting in the Fairfield-Gettysburg area and throughout the Appalachian region are the result of forces which compressed the undisturbed nearly level strata in a horizontal direction, producing folds whose axes ran at right angles to the direction of compression. The source of these forces is not known, but it is considered probable that they were due in part to the sinking of ocean basins and rising of the adjacent continents, which resulted in the slow movement of deep-seated plastic rocks beneath the sinking basins toward the rising continents. By this deep-seated movement the overlying less plastic rocks would be pushed toward and crushed against the rocks that composed the continents. Shrinkage of the interior of the earth may also have been a contributory cause of the compressive tangential forces. The shortening of the radius of the earth and corresponding shortening of its circumference would produce in the surficial more rigid portions tangential, locally horizontal stresses that could find relief only in the upfolding of the strata. Other forces, possibly astronomic, probably had a part in the mountain making.

The general overturning of anticlinal folds toward the northwest, with the attendant production of southeastward-dipping cleavage and schistosity approximately parallel to the axial planes of the folds, and the prevalent overthrusting of the rocks toward the northwest on fault planes indicate that the deformative force throughout the Appalachian region was a push from the southeast. Further evidence of the direction of the force is afforded by the increased intensity of the folding and alteration of the rocks toward the southeast, which reaches a maximum in the Blue Ridge and Piedmont provinces. The fact that the ocean basin lay toward the southeast lends weight to the assumption that the sinking of this basin played a large part in the production of the forces and in determining their direction.

Carboniferous and all older rocks throughout the Appalachian region are involved in the folding and thrust faulting, whereas the late Triassic strata east of the Blue Ridge are not affected by it but are only tilted and slightly warped. The intense compression of the rocks and attendant uplift of the epicontinental sea bottom into permanent land must therefore have taken place in late Carboniferous or early Triassic time. Folding on a smaller scale had occurred during the Paleozoic period of sedimentation, particularly in the eastern part of the region, and some anticlinal axes were temporarily raised above the sea, causing irregularity in the thickness and distribution of the deposits, but the earth movements in this region culminated in the great mountain-making disturbance near the end of Carboniferous time.

The trend of the longitudinal folds of the Cambrian siliceous rocks of South Mountain changes from west-southwest east of the Fairfield quadrangle to south-southwest in this quadrangle, and this change is accompanied by the abrupt ending of the westernmost ridge of the mountains in the area, which is due to the southward plunging of the Big Flat Ridge anticline. It is believed that the first folds to develop during the compression were those nearest to the source of the pressure, where the intensity of the force was greatest—that is, on the southeast. Therefore, in the part of the Fairfield quadrangle north of the Chambersburg pike the Big Hill-Bear Mountain anticline was the first to rise. Later other folds were formed on the west, chief of which was the Big Flat Ridge anticline, on the western edge of the uplift. This became a very broad, massive fold, which seems to have blocked the further movement of the rocks westward, and the strata to the east of it became crumpled into closely compressed and faulted folds, which have been described as the Wildcat Hill and Piney Mountain anticlines and associated synclines.

The Big Flat Ridge anticline plunges abruptly southward so that the Cambrian sandstone passes beneath the limestones at Conococheague Creek. These overlying limestones also partook of the anticlinal folding but were not resistant enough to stop the westward movement of the rocks. (See figs. 13, 14.)

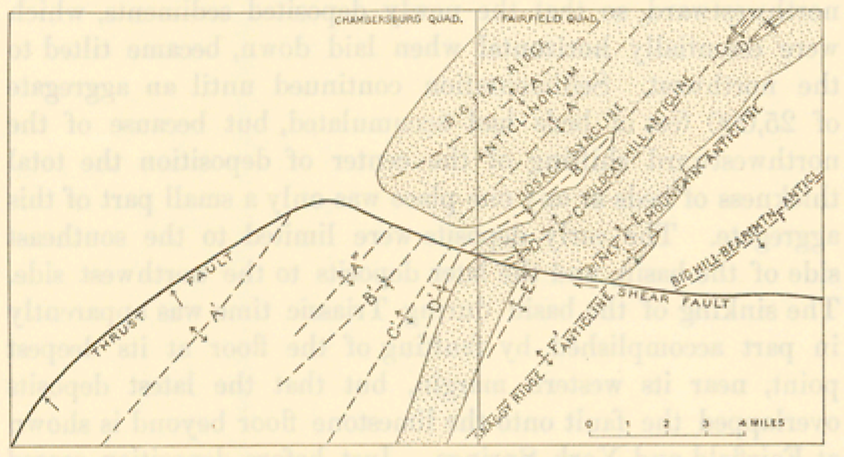


FIGURE 13.—Sketch map showing offset of the structural axes by the Carbaugh-Marsh Creek shear fault
Dot pattern, Cambrian quartzose rocks

The tendency, therefore, was for the rocks south of Conococheague Creek to move bodily westward past those that were blocked by the Big Flat Ridge buttress north of the creek, resulting in a great shearing movement that produced the Carbaugh-Marsh Creek fault. The strata were first sharply flexed along this line and then broken and offset along a nearly vertical plane, the strata on the south moving 2 miles or more to the west of those on the north. The axis of the Big Hill-Bear Mountain anticline was shifted to Snaggy Ridge, the Weverton sandstone of Piney Mountain to Rocky Mountain, and the Big Flat Ridge anticline to the limestone folds from Aqua through New Franklin and from Aula to Clay Hill.

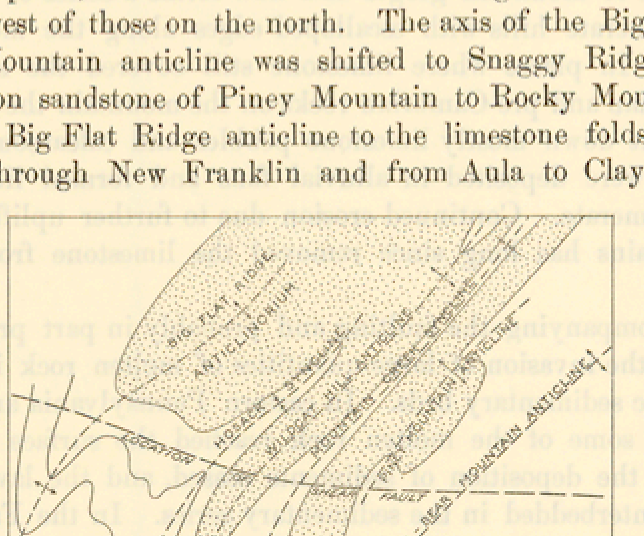


FIGURE 14.—Sketch map showing the theoretical restoration of the folds before the Carbaugh-Marsh Creek faulting
Dot pattern, Cambrian quartzose rocks

The fault plane follows the valley of upper Marsh Creek across the low divide near Newman School and down the valley of Carbaugh Run and Conococheague Creek to the western edge of the quadrangle. Here it passes into the limestones under thick deposits of terrace gravel and can not be traced, but it undoubtedly connects with the thrust fault that passes southwestward through Aqua and west of Greencastle. Thus the westward movement that produced the offset of the rocks of the mountain along the shear plane passed into the thrust fault on the west. At the same time there was a shearing along a nearly vertical diagonal break—the Antietam Cove fault—on the south side of this Snowy Mountain block, the block rising and moving southwestward, offsetting the base of the Cambrian from the north end of Green Ridge to the south end of Snowy Mountain. This block seems to be in the nature of a wedge forced forward and upward between diverging breaks diagonal to the direction of pressure. (See fig. 11.)

TRIASSIC AREA

Tilting of beds.—The Triassic sedimentary rocks at the surface strike on the average N. 30°-40° E. and dip generally from 10° to 35° NW., with an average of 20°. In the vicinity of some of the intrusive masses, however, the strike is deflected almost at right angles and the dip is increased to 55°. The prevalent monoclinal northwestward dip suggests at first that the apparent bedding is in reality cross-bedding or foreset bedding. However, many facts—for example, that individual beds and aggregates of beds maintain the same character for many miles along their strike, that the strike is uniformly straight for long distances, and that the dip is so uniform—make this explanation unwarranted. Beyond doubt the inclination of the beds was produced by deformation since the beds were laid down and is not that of the original sedimentation.

Normal faulting.—The belt of Triassic rocks is bounded on the west by a normal fault or chain of faults. Nowhere was this fault plane or even the contact between the Triassic and the adjacent rocks observed, for the conglomerates that compose most of the western border of the Triassic are largely unconsolidated at the surface. The fault is established by several criteria. (1) Gently folded intrusive sills forming crescentic hills (such as the sill southwest of Orrtanna, the larger one northeast of Hilltown, and the smaller sheets south of Bendersville) are abruptly terminated along this line; (2) nowhere in the area do the Triassic rocks overlap and rest on the pre-Cambrian rocks west of this line, but they terminate abruptly at the foot of steep slopes of these rocks; (3) the fanglomerates and coarse sandstones adjacent to the mountains are not composed chiefly of fragments of pre-Cambrian rocks, as they would be if they were derived from the rocks exposed hundreds of feet higher on the adjacent slopes, but in most places they are made up of Cambrian quartzite and sandstone and in other places of Cambrian and Ordovician limestone, showing that when they were deposited the adjacent slopes were composed respectively of quartzite and limestone; (4) the Paleozoic limestone floor on which the Triassic sediments rest south of Orrtanna, near York Springs in the Carlisle quadrangle, and presumably elsewhere throughout the Triassic basin, now stands at the foot of mountains composed of pre-Cambrian rock, whereas formerly it was continuous with the limestone which was on top of the pre-Cambrian and Cambrian rocks and from which the Triassic limestone conglomerate was derived. (See fig. 15.) The limestone floor has therefore been dropped an amount equal at least to the thickness of the Cambrian siliceous sedimentary rocks plus the height of the present mountain above the plain, probably more than 6,000 feet.

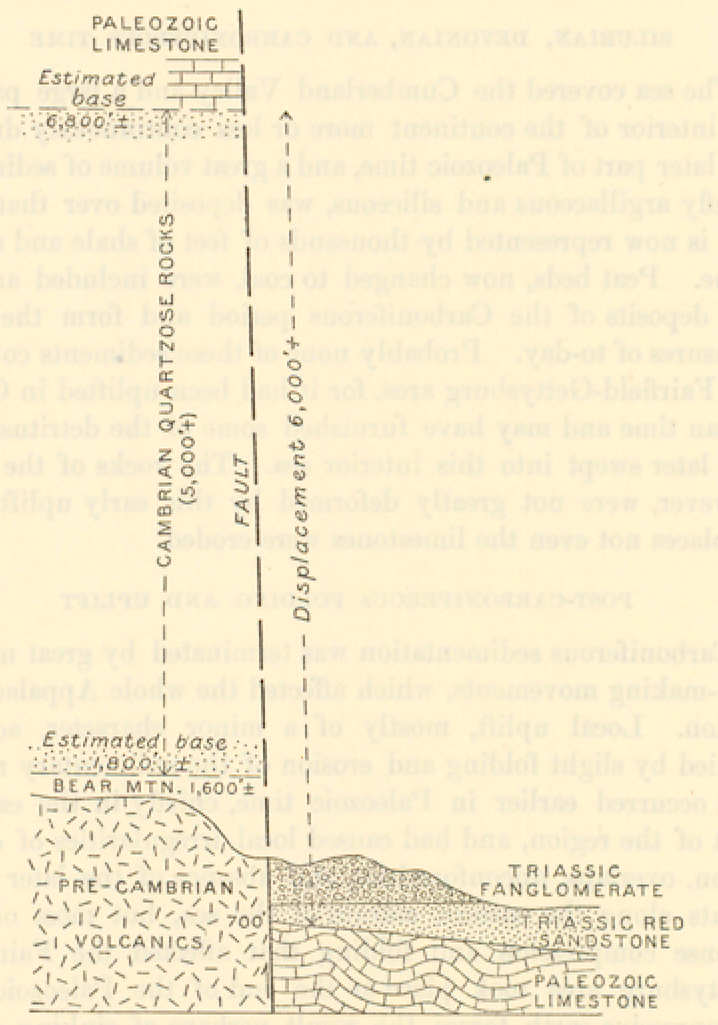


FIGURE 15.—Ideal section showing amount of vertical displacement of the rocks on the Triassic marginal fault at Bear Mountain

Age of the structure.—Cambrian quartzites must have formed the high land west of Arendtsville, Biglerville, and Bendersville when the quartzite fanglomerate was deposited. Cambrian quartzite is now present along the mountain front at only one place, Rock Top, where it has been protected from erosion by being partly faulted down with the adjacent Triassic beds. The coarseness and subangularity of many of the quartzite fragments that form the Triassic fanglomerate show that they were derived from an uplifted mass, so it is certain that the uplift of the South Mountain tract to the west by faulting had begun before these, the latest Triassic sediments, were deposited.

The tilting of the Triassic rocks, although rather uniform throughout the area, was probably not all produced at one time but by degrees. Sinking of the floor of the Triassic basin is believed to have begun at the east and progressed westward during the deposition of the sediments, gradually tilting the deposits. The sinking and tilting were in part accomplished by normal faulting near the western margin of the basin during deposition, as illustrated in Figure 6. The dip of the beds was no doubt accentuated by the general tilting of the block by the down faulting of the western part of the basin several thousand feet along the bounding normal fault at the end of the Triassic period.

PALEOZOIC AREA EAST OF THE TRIASSIC BASIN

East of the Triassic area are exposed Paleozoic rocks which have been intensely folded, metamorphosed, and faulted. They are an eastward extension of the rocks that form the floor on which the Triassic sediments were deposited and that are now exposed at Fairfield. The limestones are compressed into nearly east-west folds, which are broken by thrust faults. The hill south of Bittinger is composed of Cambrian Antietam sandstone brought up in an anticline which is faulted on its north side and overthrust onto younger limestones. The belt of shale of the Kinzers formation, which encircles the sandstone hill on its southwest side in the direction of the plunging anticlinal axis, is also cut off by the thrust fault. The curving belt of shale hills east of Bittinger similarly encircles Antietam sandstone in another faulted anticline which forms the Hershey Hills just east of the Gettysburg quadrangle. These thrust faults are of late Paleozoic age and pass beneath the Triassic sediments to the west.

The part of the Pigeon Hills that comes into this area constitutes the end of a plunging anticline in which pre-Cambrian rocks, exposed at its axis, are flanked by Cambrian quartzites. The anticline is broken by faults which are apparently of normal type but which do not affect the Triassic rocks and are therefore older than these rocks, probably early Triassic. The relation of these and other minor folds and faults to the main Pigeon Hills anticline is shown in Figure 16.

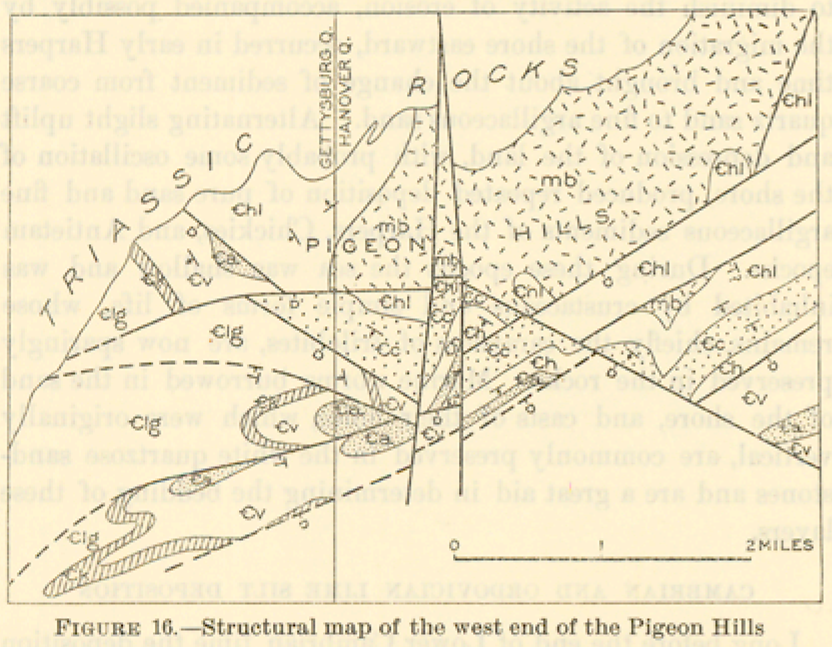


FIGURE 16.—Structural map of the west end of the Pigeon Hills
Mapping by G. W. Stose and A. I. Jonas. The main structural feature is a westward-plunging anticline broken by faults on its south side. Most of the faults are apparently of normal type, the blocks on the south having dropped. Two minor anticlines on the southwest end are broken and apparently overthrust on their north sides. The whole area is crossed by two north-south normal faults which offset the Triassic rocks and the other faults. Єlg, Ledger dolomite; Єk, Kinzers formation; Єv, Vintage dolomite; Єa, Antietam sandstone; Єh, Harpers schist; Єc, Chickies quartzite; Єhl, Hellam conglomerate member of Chickies quartzite; mb, pre-Cambrian metabasalt; D, downthrow of normal fault; T, overthrust side of thrust fault

In the southeast corner of the Gettysburg quadrangle much metamorphosed Harpers schist, in which the bedding is nearly obliterated by cleavage and schistosity, is faulted against the limestone of the lowland. The facts that these Cambrian rocks are much more metamorphosed than the adjacent limestone and that the schistosity trends uniformly southeast suggest that the fault is an overthrust from the southeast. However, the Triassic sediments are offset by a fault at Littlestown, just south of the quadrangle, showing that at this place the limestone has been uplifted by a normal fault, which apparently represents a later movement in the opposite direction along a plane that cuts the thrust fault diagonally.

HISTORICAL GEOLOGY

The geologic history of the Fairfield and Gettysburg quadrangles is recorded chiefly in their rocks but is in part preserved in their surface features—mountain tops, plateau remnants, streams and stream terraces, and gorges. Most of the history related below may be interpreted from the facts presented in the description of the formations and of the topography.

PRE-CAMBRIAN TIME

The record displayed in the rocks of these quadrangles begins with a great outpouring of lava in Algonkian time. From the existence of older gneisses, granites, and schists in adjacent areas, which are believed to underlie the lavas of these quadrangles also, it is known that sediments were deposited in a sea that occupied this area in Archean time, that molten granite and other igneous rocks were injected into these sediments and the rocks that formed the old lands, and that these rocks were intricately folded, altered, and eroded before the lavas were poured out.

The lavas are of two widely different types, one rhyolitic and the other basaltic. From their distribution and relation it is concluded that in general the rhyolitic eruption was the earlier and was followed by basaltic eruption, but there may have been several recurrences of each. These lavas apparently reached the surface through great longitudinal fissures and not through small volcanic vents, and they overflowed great tracts of the land, but there were some explosive eruptions toward the end of the rhyolitic effusion, as shown by the breccias and tuffs in Buchanan Valley. There was also a small amount of basaltic tuff thrown out by explosive eruptions. After the outpouring of the lavas the pre-Cambrian rocks were subjected to compression and folding, which elevated the land and rejuvenated the streams, so that the surface was deeply eroded and reduced to a gentle plain before the Cambrian sea submerged it.

EARLY CAMBRIAN SAND AND SILT DEPOSITION

At the beginning of Cambrian time the area where now stands South Mountain, an unknown extent of the region to the west, and the adjacent part of the Piedmont province at least as far east as the Pigeon Hills, were gently depressed and occupied by a shallow arm of the sea, while the land still farther southeast was elevated. Sediment derived by waves and streams from this elevated land was deposited in this sea: first, waste from weathered Algonkian volcanic rocks in the area that was earliest submerged was slightly reworked and accumulated as poorly assorted soft purple arkose at the base of the Loudoun formation; then, as the height of the land on the southeast increased and the disintegrated rock was removed, there came fresher detritus, quartz and feldspar grains and rounded quartz pebbles, which formed the upper part of the Loudoun, the base of the Weverton, and most of the Hellam; and finally nearly pure white quartz grains and pebbles, which formed the purer upper sandstones and conglomerates of the Weverton. Depression of the land sufficient to diminish the activity of erosion, accompanied possibly by the migration of the shore eastward, occurred in early Harpers time and brought about the change of sediment from coarse quartz sand to fine argillaceous sand. Alternating slight uplift and depression of the land, with probably some oscillation of the shore, produced repeated deposition of pure sand and fine argillaceous sediments of the Harpers, Chickies, and Antietam epochs. During these epochs the sea was shallow and was inhabited by crustaceans and simple forms of life, whose remains, chiefly the carapaces of trilobites, are now sparingly preserved in the rocks. Marine worms burrowed in the sand of the shore, and casts of their holes, which were originally vertical, are commonly preserved in the white quartzose sandstones and are a great aid in determining the bedding of these layers.

CAMBRIAN AND ORDOVICIAN LIME SILT DEPOSITION

Long before the end of Lower Cambrian time the deposition of sand and clay was succeeded by that of calcareous sediment in the shallow inland sea that covered this area, and sedimentation of this kind persisted almost continuously through the rest of Cambrian time and a large part of Ordovician time, forming the thick calcareous deposits that constitute the Shenandoah group of the Cumberland and Shenandoah Valleys and other parts of the Appalachian Valley province. They comprise the Tomstown, Waynesboro, Elbrook, Conococheague, Beekmantown, Stones River, and Chambersburg formations of the region northwest of the Fairfield-Gettysburg area. It is probable that the sea covered the Fairfield-Gettysburg area during most of Shenandoah time. The change from the deposition of sand to that of calcareous mud was accompanied by an expansion of the interior Paleozoic sea, and by Upper Cambrian time this sea covered a large part of the North American continent.

This great thickness of calcareous deposits is largely free from coarse detrital material, although minute particles of clay and fine grains of sand are disseminated in some of the beds, especially toward the east, nearer the land. The land must have been of low relief and erosion very feeble throughout the epoch for the streams to have carried so little land waste into the sea. Instead of coarse detritus the streams carried calcium and magnesium carbonates and other salts dissolved from the decomposing rocks by rain water. Much of this calcareous material was secreted from the sea water by organisms and deposited on the sea bottom in the form of organic remains. Many of the purer beds are made up almost entirely of the shells, skeletons, and fragments of calcareous invertebrates. Certain beds composed of wavy laminated concentric layers were secreted by calcareous algae, and other partly siliceous, wavy, minutely lamellar beds are believed by the writer to have been similarly produced by organisms of some low order in vast colonies that formed great sheetlike membranes on the sea bottom. The many and abrupt alternations of highly calcic and highly magnesian beds through great thicknesses suggest chemical precipitation in a shallow part of the sea, and not chemical alteration after the rocks were formed, as is believed by some. Limestone "edgewise" conglomerate, composed of flat fragments in a matrix of fine-grained limestone, is believed to have been derived from freshly deposited limy silt dried at the surface during the temporary withdrawal of the sea, broken into small flat fragments by the returning waters, and inclosed as pebbles in the overspread limy silt, but somewhat similar conglomerates are believed by some to have been precipitated by algae.

Although during this period of calcareous deposition the adjacent land was in general of low relief, it must have had a minor uplift in Waynesboro time, during which red soil, fine siliceous mud, and quartz sand from the decomposed siliceous rocks were swept into the sea and deposited to form shale and sandstone. Again at the beginning of Conococheague time an uplift occurred that raised a part of the sea bottom into land, for freshly deposited limestone was broken up, and its fragments were rounded into pebbles and formed limestone conglomerates in which considerable rounded quartz sand was also inclosed.

Throughout the epoch of calcareous deposition the inland sea was probably shallow, the deeper parts being not more than 250 to 300 feet in depth, as it was inhabited by trilobites, mollusks, and algae. It was at times so shallow that the bottom was in places affected by currents and waves, as indicated by the irregular bedding and ripple marks in some of the beds.

ORDOVICIAN CARBONACEOUS SILT DEPOSITION

In the Cumberland Valley, west of this area, marine conditions continued to the end of Ordovician time, but the sediment changed from limy silt to dark carbonaceous clay. The southeastern margin of the sea floor was uplifted slightly at about this time, and the newly deposited sediments were partly eroded, for the impure Conestoga limestone deposited at this time in the southeast corner of the Gettysburg quadrangle and the region to the east overlies unconformably the eroded edges of all the older limestones. Its impurities consist of dark argillaceous matter similar to the dark clay deposited to the northwest and probably came from the same source. The carbonaceous silt probably came from colder lands to the north, where undecomposed organic matter was brought into the sea with silt so fine that it remained in suspension a long time and was distributed widely over the shallow sea bottom by currents. Finally the silt was followed by coarse quartz sand with rounded pebbles, indicating a rejuvenation of the streams on the adjacent land by uplift and steepened grades. Marine conditions prevailed in this area during a considerable part of the Ordovician period, but it is probable that the uplift of the land to the east caused the permanent withdrawal of the sea from this area in late Ordovician time.

SILURIAN, DEVONIAN, AND CARBONIFEROUS TIME

The sea covered the Cumberland Valley and a large part of the interior of the continent more or less continuously during the later part of Paleozoic time, and a great volume of sediment, chiefly argillaceous and siliceous, was deposited over that area and is now represented by thousands of feet of shale and sandstone. Peat beds, now changed to coal, were included among the deposits of the Carboniferous period and form the coal measures of to-day. Probably none of these sediments covered the Fairfield-Gettysburg area, for it had been uplifted in Ordovician time and may have furnished some of the detritus that was later swept into this interior sea. The rocks of the area, however, were not greatly deformed by this early uplift, and in places not even the limestones were eroded.

POST-CARBONIFEROUS FOLDING AND UPLIFT

Carboniferous sedimentation was terminated by great mountain-making movements, which affected the whole Appalachian region. Local uplift, mostly of a minor character, accompanied by slight folding and erosion of the sedimentary rocks, had occurred earlier in Paleozoic time, chiefly in the eastern part of the region, and had caused local irregularities of deposition, overlaps, unconformities, and absence of the later sediments along the eastern margin of the sea, but most of the intense compression and folding that affected the Fairfield-Gettysburg area took place at the end of the Paleozoic era. Compressive earth forces, the result perhaps of sinking ocean bottoms and rising land masses and possibly of the contraction of the earth, or some other equally potent earth movements not at present understood, accumulated in the earth's interior during the relatively quiescent depositional periods from Cambrian to Carboniferous. At the end of Carboniferous time the pent-up stresses became greater than the strength of the rocks, and the newly deposited sedimentary rocks yielded by folding and faulting.

The forces that affected the rocks of the Appalachian region were tangential stresses that acted almost horizontally from the southeast, and the resultant folds trended approximately at right angles to this direction, or about parallel to the old shore line. The rocks were so intensely folded that they occupied about half their original horizontal width. This great compression and folding further consolidated the already compacted muds and sands of the sedimentary beds into firm rocks, and the constitution and texture of some of them were materially altered by the growth of new minerals and the formation of cleavage and joint planes. The rocks of South Mountain and regions to the east were the most affected by this metamorphism.

TRIASSIC SEDIMENTATION, FAULTING, AND IGNEOUS ACTIVITY

The uplift at the end of the Carboniferous period left an elongated depression between a low limestone-covered ridge along the line of the South Mountain axis and an upland composed of pre-Cambrian and Cambrian siliceous rocks to the southeast. This long valley was floored with limestone and shale. The Triassic climate was arid, as is shown by molds of salt crystals in the shale. (See pls. 21, 22.) There were occasional torrential rains. The highland was thus subjected to intense weathering, and the disintegrated rock and soil were stained deep red by iron oxide from the weathered rock. Heavy rains washed the detritus into the basin, where it accumulated in large part in standing water, for beds of sand alternate with beds of shale, the layering showing little or no cross-bedding, and many of the beds are sharply defined and of wide extent. Practically all the material washed into the basin came from the highland to the southeast, for it is composed largely of poorly assorted arkosic grits, containing feldspar and mica derived from disintegrated granitic rocks which were exposed only in this highland. The torrential rains probably flooded the valley, forming local lakes, which expanded and coalesced at times but probably never formed a continuous lake over the whole bottom of the basin.

The basin continued to deepen during Triassic time, but the center of the basin and of deposition progressively moved northwestward, so that the newly deposited sediments, which were essentially horizontal when laid down, became tilted to the northwest. Sedimentation continued until an aggregate of 25,000 feet of beds had accumulated, but because of the northwestward shifting of the center of deposition the total thickness of beds at any one place was only a small part of this aggregate. The early deposits were limited to the southeast side of the basin, and the later deposits to the northwest side. The sinking of the basin during Triassic time was apparently in part accomplished by faulting of the floor at its deepest point, near its western margin, but that the latest deposits overlapped the fault onto the limestone floor beyond is shown at Fairfield and York Springs. Just before deposition ceased the northwest margin of the basin was strongly uplifted along a chain of faults that form a nearly continuous line. The part of South Mountain lying in the Fairfield-Gettysburg area was uplifted so much that the torrential rains swept from it into the basin large amounts of coarse and poorly assorted material, in part composed of subangular masses, derived from the erosion of South Mountain rocks. This material was deposited along the western border in huge alluvial fans at the mouths of mountain gorges and now forms a series of conical fanglomerate hills with escalloped edges along the mountain front. In places where limestone still covered the siliceous Cambrian and pre-Cambrian rocks on the mountain the streams brought down mostly limestone pebbles and calcareous sand, which were deposited in alluvial fans and formed limestone conglomerate. Continued erosion due to further uplift of the mountains has long since removed the limestone from their tops.

Accompanying the faulting and probably in part preceding it was the invasion of large quantities of molten rock into the Triassic sedimentary beds. In eastern Pennsylvania and New Jersey some of the molten rock reached the surface as lava before the deposition of sediments ceased, and the lava flows were interbedded in the sedimentary series. In the Fairfield-Gettysburg area a small sheet in the upper part of the sedimentary series south of Bendersville is apparently such a lava flow, so that here also the invasion of the igneous rock began before sedimentation ended. The molten rock came from great depths, where the internal heat is much above the melting point of the rocks at the surface of the earth. This deep-seated rock melted probably because of a local reduction of pressure and ascended through the fissures and faults in the rock floor into the Triassic sediments. Most of the molten rock cooled and hardened in the nearly vertical conduit up which it rose from the earth's interior and also in adjacent cracks and crevices, forming dikes that run out from the larger bodies and cut across the bedding of the sedimentary rocks. Some also forced its way between the layers of the sedimentary rocks and hardened there as sills. The molten rock and accompanying hot solutions altered or baked the soft sedimentary rocks into hard argillite or hornfels, in which were developed many new minerals, and in places deposits of magnetite of considerable size were formed.

JURASSIC EROSION AND FORMATION OF KITTATINNY PENEPLAIN

Since Triassic time the whole Fairfield-Gettysburg area has been above sea level, and its surface has been subjected to erosion by atmospheric agencies during the enormous lapse of time to the present. Erosion has not continued uniformly during all this time but has varied in intensity with the change of altitude of the land. When the land rose, erosion was accelerated; when it halted or sank, erosion decreased or stopped. On the whole, the land has been gradually rising, but records of several prolonged halts in the general rise are preserved in the topography of the region. During these quiescent periods parts of the land were worn down to a peneplain (a gently rolling plain near sea level). Apparently only once was the land stationary long enough for hard, massive quartzite to be worn down to such a peneplain. In the shorter periods of quiescence only the softer rocks were worn down to the plain of erosion and formed partial peneplains or benches.

During all of Jurassic and early Cretaceous time this part of the continent remained so nearly stationary that the surface of the land in the Appalachian Highlands was largely reduced by weathering and stream erosion to a rolling peneplain which sloped gently toward the sea and toward the major drainage lines. Some unusually massive resistant rocks distant from the ocean were not entirely worn away but remained above the plain and now form some of the highest mountains of the region. Where the surface passed beneath the sea it was planed off by marine erosion and received a covering of sediments that were brought to the sea by the streams. In early Cretaceous time the surface of the plain adjacent to the sea sank gently, so that marine deposits lapped successively farther inland and a great thickness of beds accumulated, but the wearing down of the surface of the land continued until there was renewed uplift in middle Cretaceous time, which revived active erosion, and the streams began to cut their channels into the newly formed plain.

This peneplain can now be seen where it emerges from beneath the Lower Cretaceous deposits in New Jersey, eastern Pennsylvania, and Maryland. Its surface formerly rose gradually inland but is now much dissected, the parts composed of softer rocks having been entirely removed and even the portions cut on the hardest rocks having lost their original evenness. A remnant of an old peneplain surface preserved on the upturned beveled edges of quartzite beds composing the top of Kittatinny Mountain in New Jersey and Pennsylvania, now 1,700 feet above the sea, is believed to represent this stage of planation, and this surface has been named the Kittatinny peneplain.

In the Fairfield-Gettysburg area the Kittatinny peneplain is believed to be represented by the higher flat parts of South Mountain at an altitude of 1,800 to 2,000 feet. The nearly even sky line of Green Ridge at 1,800 to 1,900 feet and the broad crests of Big Flat Ridge at 1,900 feet apparently represent the surface where it was reduced nearly to a plain; the higher flat tops of Snowy Mountain and of Big Pine Flat Ridge, which are over 2,000 feet in altitude, probably represent portions of the surface that were not completely reduced to the peneplain level because they are composed of flat-lying massive resistant Cambrian quartzite. The same peneplain is preserved on North Mountain and associated ridges west of Cumberland Valley at about 2,000 feet.

The profile across the Fairfield and Gettysburg quadrangles (see fig. 17) shows a remnant of the Kittatinny peneplain on the tops of South Mountain at 1,900 to 2,000 feet. East of South Mountain the highest peneplain remnants are at 1,050 feet on the top of the Pigeon Hills in the eastern part of the Gettysburg quadrangle. Isolated higher peaks seem to be rocks in the hilltops east of Green Ridge and in many level benches within the mountains, notably in Buchanan Valley. Just south of the Fairfield quadrangle the Monterey golf links, located on this smooth surface, which is there 1,340 feet in altitude, have a rich soil of deeply decayed greenstone, indicating prolonged weathering without erosion. Undoubtedly these benches are remnants of a broad rolling plain which formerly extended across these valleys and above which rose the unreduced ridges of harder rocks. This peneplain probably represents erosion during the later part of Cretaceous time. It has been called the Weverton peneplain, from its development on the tops of sandstone ridges near Weverton, Md., at about 1,300 feet.

This plain is believed to have been faulted in the same manner as has been postulated for the Kittatinny peneplain, to be represented east of South Mountain by hilltops and benches at about 1,000 feet, and to pass beneath Upper Cretaceous sedimentary rocks east of Baltimore.

The Devils Racecourse, a topographic feature of considerable local interest in South Mountain, seems to have been determined by this peneplanation. It is a broad, flat-bottomed, steep-sided valley between parallel Cambrian quartzite ridges and was apparently the course of a well-graded stream at the level of the Weverton peneplain. The stream had cut through the hard quartzite into softer rocks beneath, in which it had eroded a flat-bottomed valley of gentle grade. Large masses of Cambrian quartzite derived from the adjacent cliffs accumulated on the valley bottom but were covered with finer material and soil. When the area was later elevated and subjected to erosion the covering of sand and soil was washed away, leaving the level pavement of great bare boulders in the flat bottom of the valley. (See pl. 24.)

EARLY TERTIARY EROSION AND HARRISBURG PENEPLANATION

The Cretaceous period was terminated by renewed uplift of the Appalachian region, which caused further tilting of the surface toward the sea and increased the erosive activity of the streams. During the quiescent epoch that followed this uplift, in early Tertiary time, the softer rocks were largely eroded to a new low level and the harder rocks were trenched and some were partly worn down. The plain at this new lower level was especially well developed on the limestone and soft shale of the Appalachian Valley across Pennsylvania, Maryland, and Virginia. Between Harrisburg and Lebanon, Pa., this peneplain is now preserved in the plateau-like shale hilltops. It is so well shown in the flat-topped hills at 560 to 600 feet back of the city of Harrisburg that it has been named the Harrisburg peneplain. It rises to more than 700 feet at the divide between the Susquehanna and Potomac drainage systems on the shale hills near Chambersburg.

Many of the shale hills adjacent to the larger streams have flat tops but are at a lower altitude than the Harrisburg peneplain and represent a later stage of peneplanation.

Most of the Fairfield and Gettysburg quadrangles east of South Mountain is occupied by Triassic shales and sandstones, which are in general softer than the shales of the Appalachian Valley and have therefore been eroded below the Harrisburg level. Some of the schist hills in the southeastern part of the area have even tops at 680 to 720 feet, and these may represent the Harrisburg peneplain at about the same level as the peneplain at Chambersburg. Flat-topped summits and benches at this altitude also occur on the diabase hills along the western part of the Gettysburg Plain, as is especially well shown east of Fairfield. Benches have been cut at this level on the spurs on the east front of South Mountain, but there is a somewhat higher terrace at an altitude of about 800 feet which seems equally prominent.

Several gravel fans forming terraces at the mouths of large mountain gorges at an altitude of 700 feet, such as those east of Hilltown and Cashtown, probably were in part laid down on the Harrisburg plain. The outer portions of some of these gravel fans extend down to 600 feet and were deposited later than the Harrisburg epoch.

During the Harrisburg epoch large lateral branches of the trunk streams, the Potomac and Susquehanna, which followed the belts of soft rocks, had such gentle grades on the lowland surface of the Harrisburg peneplain that their courses became very winding. When the activity of stream cutting was increased by uplift and tilting of the peneplain these streams began again to cut down their channels, which then became intrenched in deep meanders in the soft rocks, and these meanders have persisted to the present time. The large streams in the Appalachian Valley show these incised meanders to the greatest perfection, but the winding courses of Conewago Creek and its South Branch and of some others of the larger streams in the area probably originated on a still lower peneplain.

The Harrisburg peneplain has not been clearly distinguished from other peneplains over the Piedmont province, to the east, and its relations to the sedimentary rocks of the Coastal Plain are not fully established, but it is believed to be the equivalent of the floor on which Eocene sedimentary rocks rest and therefore to be of early Tertiary age.

LATER TERTIARY EROSION AND BRYN MAWR PENEPLANATION

In later Tertiary time the land was again uplifted and tilted slightly toward the sea, and much of the Harrisburg peneplain was eroded to a lower level by the renewed activity of the streams. In the Fairfield-Gettysburg area only the portions of the older plain that were cut on harder rocks, such as the Triassic diabase, or were protected by gravel outwash, resisted erosion to the lower level. Most of the Gettysburg Plain, which is underlain by the soft Triassic shales, was reduced to a gently rolling plain, large tracts of which, especially in the vicinity of Bonneauville, Whitehall, and Germantown, stand at an altitude of about 600 feet. This plain is called the Bryn Mawr peneplain. If the valleys that have since been cut into this old surface were filled, the plain would be restored with but few eminences rising above it other than the diabase hills and the gravel-covered terraces. Several of the gravel deposits, particularly those in the vicinity of McKnightstown, descend to the level of this lower plain. The harder schist hills southeast of the Gettysburg quadrangle were not reduced to this level, but it is represented by a terrace along the western border at an altitude of about 600 feet. This terrace can be traced to Potomac River, and along the river it is generally covered with remnants of stream gravel. About 10 miles west of Washington it is 500 feet above sea level and is covered with the Bryn Mawr gravel (formerly called "Lafayette formation"), of Pliocene (?) age. The age of the plain is thus established as probably Pliocene.

The courses of the streams in the Gettysburg Plain were probably established approximately in their present position on the Bryn Mawr peneplain, and when this plain was uplifted they became intrenched, so that their winding courses have become fixed in position, although slightly modified in shape in later times.

QUATERNARY EROSION

Since the formation of the Bryn Mawr peneplain the region has been again uplifted and tilted toward the sea. The steps in this uplift are well shown by the records preserved on the Coastal Plain of Maryland and comprise four periods of elevation, each followed by a period of quiescence or slight sinking. After each of the periods of uplift broad benches were cut into the shores by the waves of the sea and of the estuaries, and these benches were covered by gravel and sand and are preserved to-day as gravel-covered terraces bordering the seacoast at successively higher levels. These terraces are well defined up the valleys of the main streams to the points where the streams emerge from their rock gorges at the "fall line." The uplifts and halts of the land also affected the cutting power of the main streams and their tributaries above the mouths of the gorges and are recorded in portions of the region by plains and benches cut in the soft rocks. Remnants of these elevated benches or terraces along the streams are largely covered by stream gravel.

In the Fairfield and Gettysburg quadrangles gravel-covered terraces occur along the present streams, but the region is so distant from the master streams, the Potomac and Susquehanna, that the different levels which correspond to the quiescent periods between the uplifts can not be recognized. The highest gravel of this character is 80 feet above the present drainage level, but this area has probably been elevated more than 200 feet since Bryn Mawr time.

The streams are now slowly cutting their channels to a new low level and have narrow, steep-sided valleys where they pass through harder rocks but in the softer rocks have widened their valleys into rather broad silt-covered plains. This is well shown by Conewago Creek, which has a narrow gorge where it passes through the hard diabase sill at Newchester and a broad flood plain on the soft Triassic sandstone above and below. This creek also illustrates the increased windings which a stream acquires as it cuts deeper and deeper into the plain, its former shorter course being represented by the gravel-covered necks of land on the inside of the oxbows. East of Waldheim the Conewago is so rapidly cutting its right bank that before long it will undoubtedly sever the narrow neck of land and follow a short cut, abandoning the long loop past Hafers Mill.

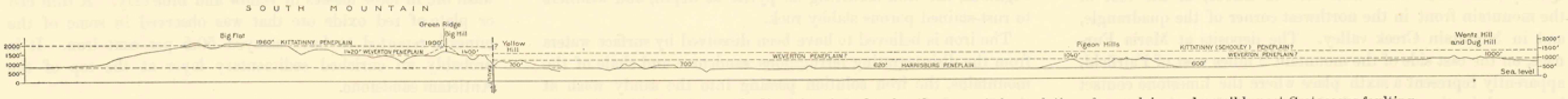


FIGURE 17.—Profile from northwest to southeast across the Fairfield-Gettysburg area and adjacent region, showing the suggested correlation of peneplains and possible post Cretaceous faulting

ECONOMIC GEOLOGY

The mineral deposits known to occur in the Fairfield-Gettysburg area are iron ore, copper, asbestos, slate, greenstone used for artificial slate, garnet abrasive, whetstone, vein quartz, quartz sand, gravel and boulders, clay and shale for brick manufacture, limestone, building stone, flagstone, slate, crushed rock, monumental stone, and marble. Most of these deposits are of commercial value or have been worked to some extent. In addition to these, phosphorus and manganese ores and white paper clay occur in association with some of the brown iron ore, and the rather rare red mineral piedmontite may be of value for mineral collections. A well was drilled for oil in the South Mountain portion of the area, and coal was reported from the Triassic sandstones near Aspers, but there is no evidence of a deposit of either of these products in the region. The soils and water supply are of known economic value.

IRON ORE

BROWN ORES IN SOUTH MOUNTAIN

General occurrence.—Brown iron ore (limonite and other hydrous oxides of iron) occurs throughout the length of South Mountain, along its border adjacent to the limestone. In places these deposits are large and of high grade, and many thousand tons has been mined in the past. At present little or no mining is being done. The larger known deposits have been extracted to the limit of profitable working, and the low price of ore of this kind at the present time confines its production to readily accessible, easily mined deposits.

The brown ore occurs chiefly in the wash and residual clay that cover the contact of the quartzite of the mountain and the limestone of the valley. It is found in irregular masses ranging from fine grains to bodies several tons in weight and in general is rough surfaced, pitted, and cavernous but in part smooth surfaced, black, and dense. The larger masses are inclosed in plastic yellow clay, which, in some of the pits, rests on the irregular solution surface of the underlying limestone. Some of the ore is associated with pure-white clay. The smaller masses are scattered through yellow to purplish-red clay and are mixed with fragments of quartzite and more or less rounded quartzitic boulders.

This ore belt follows the limestone-quartzite contact and enters the Fairfield quadrangle at five places—on the east side of the faulted synclinal valley of Antietam Cove, in the flat valley of Conococheague Creek west of Caledonia Park, in the syncline which forms the narrow valleys southeast of the Quarry Hill and Wolf Hill line of knobs, at the foot of the mountain front in the northwest corner of the quadrangle, and in Mountain Creek valley. The deposits at Maria Furnace, on the east side of the mountain 2 miles west of Fairfield, apparently represent a sixth place where the limestone contact is exposed in the quadrangle, but the relations there are not fully known.

No deposits of ore have been found in Antietam Cove, but there is no known reason why such deposits should not occur there, deeply buried by the mountain wash.

In the syncline southeast of Quarry Hill ore banks were opened at the forks of Hosack Run, a mile above its mouth. The ore is in part an iron-cemented brecciated quartzite, which has probably resulted from crushing of the rock on the east side of the faulted syncline. The pits and dumps of this old mine are nearly obliterated by slumping and filling with wash, and no record of the amount of ore extracted is available. On the west side of this syncline ore was mined by a tunnel in the face of Wolf Hill. On the north side of Conococheague Creek just west of the old Caledonia furnace ore was mined by a drift into the hill. This ore also is a cemented brecciated quartzite, in the crushed syncline adjacent to the large fault that passes up Conococheague Valley. The output of these mines is not known, but for a time they supplied the Caledonia furnace with ore.

In the short strip of the ore belt that crosses the northwest corner of the quadrangle there is an old ore pit that belonged to the Cleversburg group of mines, and just to the southwest, across Furnace Run, there is another old pit close to the quartzite ledges. Other old pits of the Cleversburg group lie to the northeast.

Ore is not known to have been found in the small area of the Mountain Creek belt within the Fairfield quadrangle, but large quantities were mined a few miles to the north. At Maria Furnace, on the east side of South Mountain, a large ore bank has been worked, and, although the geologic relations are not fully determined, it is probable that the ore is underlain by limestone adjacent to the crushed quartzite exposed in the railroad cut to the west, which is probably Antietam. The relations are believed to be the same as those at the west base of the mountains. The deposit that was worked to the northeast, farther out in the limestone, has similar relations, but the underlying limestone is separated from the quartzite by a fault.

Mining industry.—During the active mining in this vicinity up to about 1890 most of the ore that was under sufficiently light cover to be profitably extracted by means of open pits was removed. Mining has for the present ceased in this region, partly because the deposits that remain can be worked only by drifting but chiefly because of the immense deposits of easily accessible richer ores that have been opened up in the Lake Superior and southern Appalachian regions.

Slag heaps and stone ruins mark the location of several iron furnaces that were in operation in this region during the height of the mining activity. One of the largest was the Montalto furnace, at the present site of Montalto Park, at the west foot of the mountain a few miles west of the South Mountain Sanatorium. The Caledonia furnace was on the Chambersburg pike at what is now Caledonia Park, the Maria furnace was 2 miles west of Fairfield, and several others were only a few miles outside the Fairfield quadrangle.

Charcoal for these furnaces was obtained from the neighboring mountains, where the woods are still interlaced with old charcoal roads and dotted with round level bare spots where the wood was burned to charcoal. Later coal was substituted in some of the furnaces. A part of the pig iron was wrought in forges and rolling mills in the vicinity, one of which was located in Antietam Cove and another on Conococheague Creek just west of the Caledonia furnace, now represented only by ruins.

The ore varies considerably in its content of iron, phosphorus, silica, and manganese. The phosphorus is generally rather high in the ores along the foot of the mountain. The mean of 13 analyses[a] of dried ore from the Montalto property gave iron 46.05 per cent, manganese 1.11 per cent, phosphorus 0.27 per cent. Some samples ran as high as 55 per cent of iron and 0.44 per cent of phosphorus. Sulphur is usually low, and silica ranges from 8 to 20 per cent.

Nature and origin of the deposits.—The chief bodies of brown iron ore in the South Mountain region occur persistently at or near the contact of the limestone and quartzite series. At present many of the old mines are water-filled holes with slumped clay banks, in the bottom of a few of which limestone is exposed. The early investigators, therefore, had the advantage of freshly exposed sections in open cuts and drifts.

The ores are secondary deposits in residual clay segregated from the disintegrating sedimentary rocks of the vicinity. Many of the thinner shaly beds of sandstone and sandy shale in the mountains are so heavily impregnated with iron oxide that they form a low-grade ore, and some sandstone beds are thickly studded with magnetite crystals. The calcareous quartzite at the top of the Antietam sandstone is especially ferruginous, the iron occurring as pyrite at depth, and weathers to rust-stained porous slabby rock.

The iron is believed to have been dissolved by surface waters from the disintegrating ferruginous sandstone and shale of the mountains, the iron solution passing into the sandy wash at the foot of the steep slope, where some of the iron was oxidized and precipitated around grains of sand, cementing them into a solid mass. Such ore is therefore very siliceous. The iron solution passing down through the wash followed the surface of the underlying less pervious limestone, slowly dissolving it in its carbonated waters and precipitating in return dense brown iron ore in the residual yellow clay that filled solution pockets in the limestone surface.

This process of deposition of iron ore has been going on slowly and constantly ever since the region was raised above the sea and erosion and disintegration of the rocks began, but the accumulation of ore proceeded more rapidly during periods of planation, when the land surface was worn down to a nearly level plain thickly mantled by rock waste. The flow of the rivulets descending the mountain slopes was slackened as they entered the sandy wash at the foot of the slopes, a condition favorable for the solution of the limestone and deposition of iron oxide. Renewed elevation raised these areas above base-level, so that the surface of the limestone has been lowered by solution and erosion. Most of the brown iron ores along the west foot of the mountains thus occur in gravel and wash which occupy benches above the general level of the limestone valley and were in large part formed during Tertiary epochs of peneplanation.

BROWN ORES OF THE HANOVER VALLEY

Brown ores similar in character to those of South Mountain lie at the foot of the Harpers schist hills that cross the southeast corner of the Gettysburg quadrangle. This area is part of a belt of deposits that extends from Littlestown eastward beyond Hanover, Pa. The deposits occur along the fault contact of Harpers schist and the limestone and lie mostly just south of the Hanover-Littlestown road. One pit is in the limestone north of the road, near Sells Station, and two small openings are on the shale hill 1 mile back of the limestone contact. The larger ore pits along the fault contact are the Samuel Schwartz and Sol Schwartz banks, near Mount Pleasant, and the Early & Killinger, Enoch Lefevre, and Clark banks successively to the southwest. The Clark is just south of the quadrangle boundary.

[a] McCreath, A. S., Second Pennsylvania Geol. Survey Ann. Rept. for 1886, pt. 4, p. 1421, 1887.

Several thousand tons of ore has been taken from each of the larger pits, which, however, are generally not over 40 feet deep. Most of the ore was wash ore—that is, lumps scattered through yellow and blue clay from which they had to be washed—but some large lump ore occurred at the bottom. The clay is disintegrated slate and, according to old reports, merges in some of the pits into hard crystalline slate or schist. The ore extends between the layers of slate, which dip 15°–40° SE. The dip of the slate bedding was observed at only one place to be 40° NW., so that the persistent southeast layering is probably schistosity parallel to the fault plane. The ore is chiefly limonite, mostly in thin brittle shell-like plates. Some is botryoidal, manganiferous, and concretionary; some is soft and earthy; and a little was reported to be magnetic micaceous iron scattered through compact slate. The better ores, as determined by the Second Geological Survey of Pennsylvania, range in iron content from 45.93 to 49.06 per cent; manganese, 1.21 to 5.07; phosphorus, 1.11 to 1.33.

Fresh fragments of Harpers slate contain much iron pyrite, which weathers to limonite near the surface, and the weathered rock is also highly stained with iron oxide. The ore was undoubtedly derived in this way by the weathering of the pyrite in the slate. The pyrite was changed to limonite, which accumulated in pockets of disintegrated slate. Small pockets of ore occur scattered over the slate area, but the larger deposits are at the foot of the slate hills. There is no thick accumulation of rock wash at the foot of the slope, as there is along South Mountain, in which the ore could accumulate, the slate disintegrating into clay and not into gravel and sand to form wash. The shale at the fault contact is in general more deeply disintegrated than elsewhere, because surface water circulated more freely in this crushed and sheared zone. Pyrite is apparently also more plentiful there. Larger quantities of ore, therefore, accumulated along the fault zone, being derived largely from pyrite in rock that disintegrated in place, but some was transported by surface waters from decomposing slate in the hills above. Deposition has probably been going on since late Tertiary time.

BROWN ORES IN THE PIGEON HILLS

Similar brown ores occur on the flanks of the Pigeon Hills, which just enter the east side of the Gettysburg quadrangle. The only opening known in the quadrangle is an old pit on the south side of the Pigeon Hills, 1 mile northeast of Bittinger. The ore in the larger banks is reported to be chiefly wash ore in loose masses in yellow and blue clay. A thin bed or plate of red oxide ore that was observed in some of the mines is reported to have assayed 50.5 per cent iron. It is probably an enriched sedimentary layer at the top of the Antietam sandstone.

This brown ore, like the South Mountain ores, was derived from the disintegration of ferruginous calcareous transition beds at the top of the Cambrian quartzites of the Pigeon Hills, taken into solution by surface waters and precipitated in the sandstone wash at the foot of the slopes in exchange for calcium carbonate dissolved from the limestones.

SPECULAR HEMATITE

Small quantities of specular hematite are associated with quartz veins in the pre-Cambrian volcanic rocks of South Mountain, and a little is also associated with the copper deposits in the pre-Cambrian rocks. Most of the quartz veins in the area show a small amount of hematite. Even the vein that was worked for silica south of Caledonia Park shows considerable hematite in places, as do some of those in the northern part of the area, especially on the hill south of Wenksville. The quartz vein at the head of Buchanan Valley contains an unusually large quantity of hematite and has been prospected at Cole's ore bank, 2 miles north of Newman School. Although solid chunks of good ore the size of a man's fist are found, the quantity is not sufficient to be of commercial value. The vein seems to mark a fault between schistose rhyolitic breccia and massive rhyolite porphyry, and hematite is found along it and in the associated asbestos-bearing greenstone to the north.

Good showings of hematite are present in the quartz vein on the hill 1 mile west of Cashtown, which also marks a fault. Hematite is also present at the greenstone contact west of Virginia Mills and north of Marshall, which is believed to be another fault line. At the west base of the Pigeon Hills massive specular hematite in red jasper, an ore of fine grade, was found associated with the quartzite at the fault contact. It seems, therefore that most of the hematite in the area is in vein filling along or adjacent to faults.

Hematite is found in the belt of copper-bearing greenstone from Gladhill to Mount Hope, along Hayes Run, and in the prospects east of Jacks Mountain, but the quantity is too small to be of value. A little is also associated with the copper-stained Triassic rocks in the prospect pit 1 mile east of Fairfield.

MAGNETITE

General occurrence.—Extensive deposits of magnetite occur in the Triassic rocks of the adjacent Carlisle quadrangle near Dillsburg, Pa., and at Cornwall, Pa., farther east. Geologic relations in parts of the Fairfield-Gettysburg area are closely similar to those at Cornwall and Dillsburg, and it is not impossible that similar rich deposits occur in this area. Thus far only a few small workable deposits have been found, and none are at present (1927) being mined.

Mining industry.—The only deposits that have been worked to any extent in the area lie just west of Fox Hill, a little over a mile from Cashtown. The location of the two formerly active mines, the Peter Comfort and Adam Minter mines, as well as the other openings, is shown on the economic-geology map.

Nature and origin of the ore.—Magnetite is a conspicuous mineral in much of the diabase intrusive in the Triassic sediments. The soil in the roads crossing the diabase hills contains much magnetite, which was derived from the disintegration of the diabase and has been concentrated in black streaks by the surface water. Some masses of diabase are more heavily charged with these crystals of magnetite than others, that of Chestnut Hill in the Gettysburg quadrangle being most conspicuously so. None of the diabase, however, has sufficient iron to be classed as an ore.

The known deposits of magnetite in this area are in Triassic sedimentary rocks immediately adjacent to diabase and were evidently produced in the process of metamorphism of the sedimentary rock by the intrusion. In the Cornwall mine magnetite has replaced Paleozoic limestone at the upper contact of an intrusive diabase sill. In the Dillsburg mines the ores are largely due to replacement of limestone pebbles in a calcareous breccia in the Triassic sedimentary rocks at the under contact of a diabase sill. Details of these occurrences and an explanation of the origin of the ore are given by A. C. Spencer[9] in a report on the magnetite deposits of the Cornwall type, and by E. C. Harder[10] in a report on the magnetite deposits at Dillsburg. Spencer concludes that the ore bodies were formed by chemical replacement of limy rocks by iron minerals precipitated from heated solutions, and that the ore solutions, probably in the form of vapor, presumably came from the same source as the diabase intrusion which they accompanied.

The ores in the Minter and Comfort mines, in the Fairfield quadrangle, are apparently deposits similarly replacing calcareous sandstone. The wall rock is reported to be a fine calcareous conglomerate, but the specimens seen on the old mine dump indicate that magnetite, garnet, epidote, and other metamorphic minerals did not replace pebbles but resulted from the alteration of material in zones and pockets in the sandstone that was presumably calcareous and therefore favorable to alteration to metamorphic minerals. The magnetite deposits were evidently formed by the action of hot iron-laden solutions which accompanied or immediately followed the intrusion of the diabase and, circulating in the adjacent sedimentary rocks, dissolved the limestone pebbles and replaced them with magnetite and altered the calcareous sands to garnet, epidote, and other minerals. The fact that magnetite is so abundant a constituent of some of the diabase strongly favors the view that the source of the iron was the original molten magma. The more direct the connection of a diabase mass with the source of the molten magma, the hotter would be the solution and the greater the metamorphic effect on the rocks. Under the theory that the diabase in this area came into the Triassic rocks through a longitudinal vent along the bottom of the troughlike depression, the most active mineralization should be expected adjacent to diabase masses that lie near the center of the trough, such as the sheet at Carr Hill and Knoxlyn and the masses north of Center Mills which extend into the Carlisle quadrangle, and also along large cross-cutting bodies, such as that which runs south from Wilson Hill. These areas, therefore, are shown on the economic-geology map as possibly underlain by workable deposits and as favorable ground for prospecting with the drill or by magnetic dip needle. Large deposits, however, should not be expected unless limestone or limestone conglomerate overlies the sills in depth, for it is clear from a study of the Cornwall deposits that the mineralizing solutions followed the upper contact of the intruding mass and replaced only the limestone above the diabase sill, whereas the limestone on the lower side of the sill was altered by baking and shows little mineralization.

COPPER ORE

COPPER ORE IN THE PRE-CAMBRIAN VOLCANIC ROCKS

Mode of occurrence.—Copper ore, chiefly native copper, occurs in the greenstone or metabasalt of South Mountain. It is found in little grains, wires, and masses, few over an inch in size, although some masses much larger have been reported. Some of the particles are surrounded by red cuprite (copper oxide) and orange-colored hydrocuprite, and at the surface and along joint planes these are altered to green and blue copper carbonate, which stains large areas of the adjacent rock.

Copper has been found throughout the length of the large area of greenstone from the Chambersburg pike southward beyond the Maryland State line, and numerous prospects have been opened at the most promising places. Float ore has been found on the surface almost continuously between these prospects. Only a few tons of ore has been shipped from any one of these openings, although extensive development has been carried on in some, stock companies have been organized, and a furnace was constructed on Copper Run to smelt the ore. None of the openings are here classed as mines.

Origin of the ore.—The copper is believed to have been originally disseminated in the lava in the form of sulphide and to have been concentrated and reduced to native copper in the process of metamorphism of the rocks in Algonkian time. These old rocks, while they were deeply buried within the earth, were intensely compressed and heated during the earth's upheaval in Algonkian time and were greatly altered in form and composition. The water in the rocks became heated by the intense pressure and by heat from the interior of the earth, and in the presence of this hot water under great pressure chemical changes in the minerals of the rock were brought about. The vesicles in the porous lava became filled with minerals dissolved from the rock or reformed in the metamorphic processes. Quartz and epidote were the chief minerals deposited, with some calcite, chlorite, and zeolites. The copper sulphide disseminated in the rock was dissolved by the circulating water, probably as sulphate, but was possibly changed to carbonate or silicate in solution. It was later deposited together with the other minerals in favorable places by the reduction of temperature as the solution neared the surface, or by reaction with other solutions or minerals. The copper was deposited probably in the presence of a strong reducing agent, such as the ferric iron in the epidote that was being formed at the same time, and hence was deposited in the native state.

The fact that most of the copper prospects are in or adjacent to a schistose zone near the eastern edge of the large greenstone mass suggests that this contact is an old fault zone where the rocks were sheared into a schist, in which the heated waters circulated more freely. The relations observed in the Bingham opening also strongly suggest a fault, the copper solutions here penetrating the adjacent crushed and brecciated rhyolitic lava as well as the greenstone.

COPPER ORE IN TRIASSIC ROCKS

Stains of copper carbonate are numerous in the Triassic sediments and have caused considerable speculation as to possible copper deposits of value in the area. The fact that commercial deposits of copper ore occur in Triassic rocks that have been altered by diabase intrusions at the old Schuyler mine, near Arlington, N. J., gives some hope that such deposits may be found in this area, but the openings thus far made are not encouraging.

At several places in the area a little prospecting has been done. The greatest development has been made half a mile north of Hunterstown, at the north end of a diabase intrusive mass, where the shale has been altered to a brecciated slate with epidote veining bordered by pink discoloration, and a little copper and iron, which have stained the rock green and rusty. No sulphides or other indications of ore were seen on the dump.

MANGANESE ORE

Psilomelane, a manganese oxide, occurs with the brown iron ores in the Harpers schist hills in the southeastern part of the Gettysburg quadrangle, but not in sufficient quantity to be mined separately from the iron. Manganese ore, chiefly psilomelane, is associated with the residual brown iron ores of the Appalachian Valley at many places adjacent to South Mountain, and at Mount Holly Springs, a few miles north of this area, it is found in considerable quantity. No deposits of the mineral have been reported within this area, but the relations are favorable for its occurrence with the iron ores.

ASBESTOS

Small quantities of chrysotile asbestos (fibrous serpentine) occur in the pre-Cambrian greenstone of South Mountain, and several prospects have been opened in the Fairfield quadrangle. The best specimens obtained came from the dikelike band of greenstone that crosses Corls Ridge, a mile north of the South Mountain Sanatorium. The asbestos of this region occurs in small gash veins in very much altered greenstone and is probably a product of recent alteration of the rocks near the surface and not produced by deep-seated metamorphism in pre-Cambrian time. None of the deposits seen were of commercial value, owing to their small size and also to the presence of much quartz in the asbestos veins. It is doubtful if workable deposits occur in the region.

GRANULATED GREENSTONE

Granulated greenstone is used in the manufacture of roofing material. Greenstone is selected for this purpose for the reason that a substance having a natural permanent green color is desired. Although this industry is a relatively new one, a considerable demand for the product exists, and several plants are in operation in the region for grinding the stone. In the grinding process a large quantity of the greenstone becomes pulverized, and some of this material is used as a filler in composition stone, flooring, cement, rubber, and other products. Schistose greenstone is chiefly used for this purpose, because it is greener and can be crushed more cheaply than the compact variety of greenstone and also because the resulting fragments are flatter and adhere better to the matrix. Such rock occurs plentifully throughout the areas mapped as metabasalt. All the quarries from which greenstone is obtained for granulation are at and near Gladhill station (Greenstone post office) and Iron Springs. Their location is shown on the economic-geology map.

GRANULATED RHYOLITE

Rhyolite of a purplish color is also crushed to granules for red roofing material. At present only one quarry in the area is operated for this purpose. The Advance Industrial Supply Co. quarries the rhyolite in the saddle west of Pine Mountain, which it operates in connection with an adjacent greenstone quarry. The rock is crushed in the company's plant at Greenstone.

Other rhyolite in the area, particularly some in the vicinity of the South Mountain Sanatorium, is just as suitable as that now used and of better color, but it is too remote from the railroad to be economically worked.

RARE MINERALS

Rare minerals of interest to collectors and of some commercial value occur in the area. Associated with the rhyolite in places is a red mineral of a composition similar to the green epidote in the greenstone except that it contains manganese in place of iron. It is called piedmontite and is not a common mineral, having been found in few places outside South Mountain and the adjacent part of the Piedmont province, from which it received its name. Excellent specimens of the mineral are found in the rhyolite near the greenstone contact at two places on the west side of Buchanan Valley, northwest of Boyd School, and on the west side of Pine Mountain. The mineral fills thin crevices and veins in brecciated rhyolite, and some of the veins are as much as a quarter of an inch in thickness and several inches in length. It has a deep, rich red color and fibrous texture and shows on the surface finely radiate glistening crystal aggregates.

GARNET ABRASIVE

Garnet, which makes a good abrasive, is a metamorphic product that accompanies the intrusion of diabase into limestone or calcareous sediments in this area. Small nodules and masses of the minerals are associated with the magnetite in the deposits south of Fox Hill, and it is also present in small amounts in other metamorphosed calcareous Triassic sediments. North of Fairfield, where the diabase stock and sill have been intruded between the Paleozoic limestone and the Triassic sediments, some of the limestone has been extensively altered to garnet, and the soil in the fields is filled with large and small masses of granular yellowish garnet, which can be distinguished from other rock fragments by its greater weight. At the northwest foot of Sugarloaf the fields are so filled with garnet masses that they obstruct plowing, and the quantity of garnet float is apparently sufficient to be of commercial value. A similar occurrence of garnet in the soil which also may be of commercial value is found $1\frac{1}{2}$ miles farther north, on the north side of Muddy Creek. These prospects are located on the economic-geology map. The mineral has not been seen in bedrock at these places. The abrasive quality of the garnet has not been tested.

WHETSTONE

A siliceous slate in the rhyolitic tuff and breccia of Buchanan Valley makes a fine whetstone. The rock has not been quarried for this purpose, but its qualities are locally well known, and samples taken have been proved to be excellent. It is known to occur only near the head of the valley west of Brady School, but it may be present elsewhere in this band of tuff and breccia, which extends northeast and southwest for 5 miles. Dark siliceous slates were observed in the volcanic rocks elsewhere in Buchanan Valley but were not tested, and some of them may prove to be of similar quality. The deposit near Brady School would bear investigating.

VEIN QUARTZ

Quartz free from iron and other impurities has been quarried at several places in the northern part of the area and in the region directly north, for silica, or "flint," in crockery and tile manufacture. Quartz veins are numerous throughout the area

[9] U. S. Geol. Survey Bull. 359, 1908.
[10] Econ. Geology, vol. 5, pp. 599-622, 1910.

of volcanic rocks, and the location of the most prominent outcrops is shown on the economic-geology map. The veins are generally associated with soft sericite schist, which weathers readily, and loose residual masses of the quartz strew the surface. The veins are 1 to 2 feet thick, and masses several feet long are not uncommon.

Quartz veins are more plentiful north of the Chambersburg pike than south of it and are especially numerous at the north edge of the Fairfield quadrangle. Here the loose quartz masses were collected from the fields, and the best were hauled to a pulverizing mill at Aspers. Much of the field rock is discolored by iron from the weathering of the contained hematite and is discarded. Ledges of vein quartz have been opened by small pits where fresh rock has been quarried. Several such pits and collecting grounds are near Wenksville. The largest and the only recently active quarry in the area is 1 mile north of Wenksville. There were other quarries just north of the quadrangle, convenient to the railroad at Aspers and Mount Ida. Several veins occur on the north slope of Huckleberry Hill near Caledonia Park, and one of these was formerly quarried and the quartz pulverized in a mill just west of the quadrangle. As the quartz has some hematite impurities it must be carefully hand picked, which is true of practically all the quartz veins in the area. Quartz was also formerly quarried above Hilltown and was shipped to Lancaster.

QUARTZ SAND

Quartz sand for building and for railroad engines is obtainable along the entire west front of South Mountain, where the upper member of the Antietam sandstone usually disintegrates readily into easily workable sand deposits. Sand that is taken from the parent ledge is clean and sharp and of excellent quality, but much of the sand that is dug is taken from the wash below the outcrop and is not so clean and is generally discolored by iron oxide. There is a pit in sand of this character in the extreme northwest corner of the Fairfield quadrangle. The sand is hauled to the railroad at Shippensburg by wagon.

The other areas of Antietam sandstone in the quadrangle are not conveniently located for economical hauling of the product to market and at present are unworked, except for local use in building or on roads.

At McSherrystown very sandy limestone that has been leached of its lime at the surface is extensively quarried for sand. (See pl. 5.) The loose sand passes into firm sandrock at shallow depth, and this passes into unaltered blue sandy limestone at a depth of about 20 feet, which is the limit of workable material.

In the mountains southwest of Orrtanna disintegrated rhyolite has been dug for sand, and east of Gettysburg on the south side of Wolf Hill disintegrated diabase also has been dug for sand.

Sand can be had from alluvial and terrace deposits along the larger streams, especially Conewago and Marsh Creeks. It is used at present only locally.

GRAVEL AND BOULDERS

Gravel suitable for road material and concrete is obtainable from the stream terraces and alluvial deposits along Conewago Creek but at present is dug in these quadrangles only for local use. Some of the other streams that head in the mountains also have similar gravel. Close to the mountains the stream gravel is generally too coarse for roads and concrete. The boulders and cobble in this mountain wash are used in many places for fences and stone walls and can also be used for rustic buildings. The "ironstone" boulders that result from the spheroidal disintegration of Triassic diabase, particularly from the dense rock in narrow dikes, are much used for fences, and formed the barricades used by both armies during the battle of Gettysburg, especially on Seminary Ridge, West Confederate Avenue Hill, and Cemetery Hill.

The Triassic quartzose fanglomerate (Arendtsville lentil) along the foot of South Mountain is largely disintegrated, and its pebbles and boulders cover the surface. These are in places of suitable size for concrete, but most beds are too coarse for this purpose. A fine conglomerate at the eastern base of the Triassic at Irishtown and Red Hill School is in general firmly cemented but where disintegrated is suitable for concrete and has been locally used as road material. Residual cherty quartz from the Conestoga limestone is extensively used for gravel walks in the lowland of Conewago Valley.

CLAY AND SHALE FOR BRICK

Bricks are made in this region from soft shale and schist, from residual clay in limestone areas, and from the siliceous clay associated with the limonite ores. The soft red Triassic shales are used for brick at several places in the Fairfield-Gettysburg area. The largest brick industry is at Berlin Junction, southeast of New Oxford, where three plants are in operation.

The white clays in the old iron-ore banks in areas adjacent to the Fairfield and Gettysburg quadrangles have been extensively used in the manufacture of light-buff brick, but such clays have not yet been dug in this area. Soft weathered light-colored sericite schist in the pre-Cambrian volcanic rocks, which has practically the same composition as the white clay, can be used for the same purpose, and those in Buchanan Valley may some day be so utilized. The sericitic sedimentary schist or slate 2 miles west of Wenksville once quarried by the Pine Grove Co. for slate was later used in making brick.

Thick clay residuum from the argillaceous Conestoga limestone in the area south of McSherrystown is of excellent quality for brick manufacture. It is not used for brick in the Gettysburg quadrangle, so far as known, but is so used just south of Hanover, east of the quadrangle, and elsewhere to the east. In these clay pits the clay merges downward into leached shaly rock, also used for brick, and this passes into solid limestone beneath. Shale at the base of the Conestoga formation is dug for brick 1 mile north of McSherrystown.

PAPER AND TILE CLAY

A very pure white siliceous clay, suitable, when refined, for use in the manufacture of paper, paint, white vitrified tile, and light-colored brick, is associated with the iron ores at many places along the west base of South Mountain. It resembles in character the thick deposits of high-grade clay that are mined at Henry Clay and elsewhere in the Mountain Creek valley a few miles north of this area. The clay at Henry Clay contains 69.61 per cent of silica, 16.83 per cent of alumina, and 3.41 per cent of potash.

White clay was reported in considerable thickness in many of the old iron workings of the Mont Alto Co., just west of the Fairfield quadrangle, also in a prospect near Black Gap, west of Caledonia Park, and 22 feet of white clay is said to overlie the lump ore of the Big Pond ore bank along the mountain front just north of the quadrangle. It is therefore reasonable to assume that some white clay also accompanies the iron ores of the Fairfield quadrangle, but the larger areas of the ore belt in the adjacent quadrangles are more likely to yield workable deposits. The clay is highly siliceous and not a kaolin, so that for brick and tile it must be mixed in proper proportion with more plastic clays.

An unweathered fine-grained sericite schist, which is an altered pre-Cambrian rhyolite with visible quartz grains, was quarried by the Central Mining Co. and crushed for clay near Latimore, 5 miles north of the Gettysburg quadrangle, but the product did not prove entirely satisfactory. Fine sericitic volcanic schist in Buchanan Valley in the Fairfield quadrangle may prove of sufficient purity and fineness for this purpose. The larger bands of these schists are shown on the geologic maps.

White and light-colored clays from South Mountain are used in the Penn Tile Works at Aspers, in the northern part of the Gettysburg quadrangle, in the manufacture of white and colored floor tiles. Florida ball clay or some other plastic clay must be mixed with them to give plasticity and binding qualities. Formerly quartz obtained near Aspers was pulverized and used to reduce the shrinkage during baking, but pulverized silica sand from other sources is now used. Yellow and pink clays obtained from the vicinity of Aspers are used for red and dark-colored tiles.

LIMESTONE FOR LIME AND FLUX

Limestone was formerly extensively burned for lime around Bittinger. The Ledger dolomite in the vicinity of Bittinger contains thick beds of almost pure calcium carbonate which can be burned to high-calcium lime suitable for building plaster. Dolomite interbedded and generally quarried with the pure limestone is used for crushed stone. The rock layers in many of the quarries stand nearly vertical, and the depth to which quarrying can be carried economically is not great because the limestone occupies a flat lowland, and water from springs, streams, and rain rapidly accumulates and fills quarries and pits to the ground-water level. On account of the few natural rock outcrops in the lowland it is difficult to discover the high-grade limestone, and most of the quarries were opened on natural exposures, so it is probable that high-grade limestone occurs at many places beneath the cover of soil in the space between the quarries. Although the limestone is nearly everywhere covered with soil to considerable depth, the cover in general is not thick enough to make the cost of stripping prohibitive. The known surface distribution of the high-calcium limestone in the Ledger formation is indicated on the geologic map. One belt runs irregularly north from Bittinger. Another extends from a point near Irishtown to and beyond Red Hill School. A third small area occurs at Centennial.

There are numerous quarries at and near Bittinger, the largest of which is half a mile northeast of the railroad station. Several quarries have also been opened in the vicinity of Centennial. The location of all the quarries is shown on the economic-geology map. Most of the pure limestone now quarried is shipped for flux.

The Conestoga limestone, which lies at the surface south of a line through Centennial and Edgegrove, is not pure enough to be burned into high-grade lime, but considerable agricultural lime was formerly produced from it. The rock is largely a dark fine-grained slaty limestone with some beds of white crystalline limestone and limestone conglomerate. Many of the beds are veined with calcite.

BUILDING STONE

BROWNSTONE

Brownstone, or Triassic red sandstone, was a very popular building stone throughout the eastern part of the United States in the later part of the nineteenth century. Most of the high-grade stone came from the Connecticut Valley in New England and from New Jersey and eastern Pennsylvania. Some thick beds of Triassic sandstone in the Fairfield-Gettysburg area were quarried locally for building, and many of the historic houses around Gettysburg and hostelries and homes on the Chambersburg pike and other well-known highways were built of this rock. It was also used extensively in old arch bridges. (See pl. 20.) The local rock is of an attractive rich reddish-brown color and is especially suitable for lintels, doorsteps, and trimmings to brick and stone houses. Much of the rock, however, scales badly after years of exposure, especially exposed bedding surfaces. Moisture enters certain more porous bedding planes and expands when it freezes, causing thin sheets to scale from the bedding surface. Some layers crumble to grains under the weathering process. This weathering seems to affect the sawed stone more noticeably than the rough dressed, and buildings made of the smoothly finished dressed rock in time become rough surfaced and scarred by scaling, so that the stone has gradually become less popular and is used very little at present.

Thick beds of red or brown building stone occur chiefly in the Heidlersburg member and the upper part of the Gettysburg shale. Lighter-colored sandstone, which is somewhat firmer than the brown sandstone, occurs chiefly in the New Oxford formation. Large blocks of firm stone for dam construction were quarried 1 mile west of Gettysburg, and foundation stones for dwellings are obtained at several small quarries near Gettysburg and New Oxford. A hard white sandstone metamorphosed by a diabase sill has been quarried for building 1 mile east of Hilltown. Quarrying on a large scale has not been attempted in the area because layers of proper thickness, sufficient firmness, and good color for building stone do not occur in large quantity.

DIABASE OR "GETTYSBURG GRANITE"

Diabase, a coarse-textured crystalline rock intrusive in the Triassic sedimentary rocks, has been extensively quarried in the vicinity of Gettysburg for building stone. It is locally known in the trade as "Gettysburg granite." Because of its generally dark color it is somewhat somber for building stone, but it makes a very substantial structure. It is extensively used in Gettysburg as dressed stone in retaining walls, culverts, gutter and curb stones, steps, and monuments and as rubble in foundations. Several buildings have been constructed of it.

The diabase in the vicinity of Gettysburg has a well-defined grain and rift, so that dimension blocks having smooth surfaces and of uniform size can generally be quarried. Diabase resists weathering about as well as granite and is not as badly affected by fire. It is dense, so that it can be given a high polish and can be used for decorative work.

The chief body of diabase is the large sheet or sill that crops out in a belt a mile or two wide just southeast of Gettysburg and crosses the area diagonally northeastward. Its rocky ledges south of Gettysburg are shown in Plate 7. In most of the quarries in this belt the rock is noticeably broken by widely spaced nearly vertical joints, which are grouped into two or more systems of parallel planes. In addition it has a pronounced horizontal rift along which the rock tends to break into horizontal sheets and a vertical grain in two directions nearly at right angles to each other.

Quarries of high-grade building stone were active several years ago but are mostly idle now (1927). Nearly all were located along the west slope of the diabase hill that extends from Rocky Grove School, 2 miles east of Gettysburg, to the Baltimore pike, 2½ miles southeast of Gettysburg. They lie almost in a straight line, which trends southwest, parallel to the sides of the diabase mass and about at its middle. The high-grade rock is apparently limited to this medial zone because the diabase sill cooled simultaneously from both the top and the bottom, so that the strains which developed in the middle of the cooling mass, where it cooled more slowly, were equal in all directions, and it solidified as a homogeneous even-grained mass, which splits in one direction as readily as in another. The principal vertical grain which the rock now possesses has a northeasterly direction, parallel to the sides of the sill, and may have resulted from contractional strain on cooling or may have been produced by later compression of the solidified rock normal to this direction, at the time the joints were formed. The spacing of the quarries about half a mile apart along this medial zone is probably determined largely by accessibility, and the intervening rock along this zone is believed to be equally good. The diabase quarries will be briefly mentioned beginning at the north.

A quarry at Granite Hill, 4 miles northeast of Gettysburg, has produced both crushed stone and building stone. Stone from L. O. Beitler's quarry, at Rocky Grove School, 2 miles east of Gettysburg, was used for building, for steps, and for monuments. One mile to the southwest, just south of the Hanover road, several small quarries have produced culvert stones and steps. Some stone from a quarry on the west side of Wolf Hill has been dressed and polished in Gettysburg for monuments. Stone for use in massive walls of large buildings has been obtained from J. W. Flaharty's quarry, 1½ miles southeast of Gettysburg, southwest of Wolf Hill. Blocks of various lengths, 6 inches to 1 foot thick and 1 to 2 feet wide, were produced by the quarry of the McAllister Co., near the Baltimore pike, 1¾ miles south of Gettysburg. Bushman's quarry, on the south side of Culps Hill, 1 mile southeast of Gettysburg, was first worked for building stone but later furnished crushed stone for the Government roads of the Gettysburg reservation. B. F. Lightner's quarry, on the northeast side of Powers Hill, 2 miles south of Gettysburg, was worked for building stone and furnished the large dressed stones used in the wall around the National Cemetery in the Gettysburg Military Park. Slabs suitable for gutter and curb stones have been produced by the United States quarry, on the southwest side of Powers Hill. The Miller quarry, half a mile north of Round Top station on the Gettysburg electric railroad, has produced dressed stone for steps, lintels, culverts, and building stone. The Biggs quarry, in the lowland south of Cemetery Hill, 1 mile south of Gettysburg, has produced only crushed rock for road material.

CAMBRIAN QUARTZITE

Cambrian quartzite occurs chiefly in South Mountain, in the western part of the area, but it also occurs in the Pigeon Hills, at the east edge. Most of the Cambrian quartzite is too massive and thick bedded to yield regular-shaped stone of suitable thickness for building, but the upper layers of the Antietam sandstone are thinner bedded and more uniform in character. These thinner beds have been quarried on the east face of Quarry Hill, north of Caledonia Park, and have been used to build houses in the villages along the Chambersburg pike and on adjacent farms. Joint and bedding planes are slightly stained by iron oxide, which gives the rock a pleasing yellow or brown color. Irregular quartzite blocks obtained by quarrying the more massive beds are used in walls, fences, and dwellings along the Chambersburg pike in the mountain area. Such quartzite is popular in the construction of summer homes recently built in the mountains near the pike. It was used in the construction of the Caledonia iron furnace and other furnaces in South Mountain and is extensively used to line limekilns, for which it is well adapted because of its heat-resisting character.

FOUNDATION STONE

Many kinds of rock, usually some local rock available near the place of building, are used for foundation stone in the area. Diabase, brownstone, limestone, and quartzite, described above, are some of the best rocks used for this purpose. Besides these, compact red and green argillite (metamorphosed Triassic shale) is quarried for foundation stone at several places about Gettysburg. One of these quarries is 2 miles northwest of Gettysburg, and another is 3 miles north of the town. Gray sandy slate in the Harpers schist area in the southeast corner of the Gettysburg quadrangle is quarried at several places for use in Hanover for foundation stones. An irregularly jointed and fractured tough sandstone in the Pigeon Hills has also been quarried for similar use.

CRUSHED STONE

The crushed-stone business is one of the largest mineral-product industries in the area. Besides the normal demand for crushed stone in the general improvement and maintenance of roads, a large quantity has been used by the Government in constructing the fine macadam roads of the Gettysburg National Military Park. The increasing substitution of concrete for building stone in the construction of buildings, foundations, roads, and other engineering projects has also greatly increased the demand for crushed stone. Many of the quarries that produce crushed stone are mentioned under the headings "Building stone" and "Limestone."

Triassic diabase was used in the construction of most of the fine macadam roads of the Gettysburg Military Park. The Biggs quarry, within the military reservation, half a mile south of Cemetery Hill, supplied most of this crushed stone up to 1916. The crushed rock is of lighter color than the quarried blocks, and the roads are light gray.

Dense dark Triassic argillite (shale hardened by chemical action of heated waters that accompanied the intrusion of diabase) has been quarried at several places near Gettysburg for road material and is used on many of the roads in the vicinity. The State road to Carlisle was constructed of it, and the Government roads in the Gettysburg Military Park have been largely constructed of it since 1916. It is much cheaper to quarry and prepare than the diabase and makes a fairly good road bed but is not so durable.

Metarhyolite, a pre-Cambrian lava, has been quarried for road material at several places along the Chambersburg pike where it crosses South Mountain and also along the Shippensburg pike, 2 miles northwest of Arendtsville. The rock is very fragile and breaks readily into small angular fragments suitable for road material, but it does not bind readily.

Slate or schistose sandstone is quarried for road material to a small extent in the southeastern part of the area. The Hostetter quarry, 2 miles south of McSherrystown, is a large shallow pit in a dark-gray to blue slaty sandstone. The rock is hard and durable and breaks into angular fragments but does not bind well. Some of this rock is used for foundations. Similar road material was also obtained from Stoner's quarry just east of Sells Station. The rock in this quarry is a dense dark-blue glistening sandy schist or slate, which is strongly jointed and breaks into irregular angular fragments but weathers into buff shaly fragments.

In the southeastern part of the Gettysburg quadrangle the impure earthy limestone of the Conestoga formation was quarried at McSherrystown and at several other places southwestward toward Littlestown for use on roads and for ballast on electric and steam railroads. Dolomite and impure layers interbedded with the high-calcium limestone quarried for lime and flux in the vicinity of Bittinger are also extensively crushed for road material and concrete. Descriptions of these quarries are given under the heading "Limestone." The binding quality of limestone for road material is superior to that of most other kinds of rock. A sprinkling of asphaltum binder on the surface of a macadam pavement of any kind of rock, however, improves its binding qualities and makes it waterproof and more enduring.

Antietam sandstone quarried in the hill south of Bittinger is especially suitable for railroad ballast, as it naturally breaks up into cobble-size fragments and is conveniently located on the railroad. Blocks of desirable size can be had at the surface and to considerable depth. It might also serve for the first course or foundation of macadam pavements. Similar broken quartzite occurs on the surface of the sandstone hills just east of Bittinger.

FLAGSTONES

Slabby sandstone, rhyolite, and schist have been quarried in South Mountain on a small scale for rough flagging, rural walks, culverts, and similar purposes. On the east side of Buchanan Valley, for 1 or 2 miles north of Brady School, slabby sandy schist, probably an infolded mass of the Loudoun formation, is readily accessible from the road, and large slabs of the surface rock have been used for local purposes.

Much of the sandstone in the Loudoun formation breaks readily into great slabs, and large rough flags of this rock may be had on the east slope of Piney Mountain and the west side of Mountain Creek valley and elsewhere along the outcrop of the formation in the Fairfield quadrangle. Some of the hard rhyolite porphyry has a schistose structure so that it weathers into large rough-surfaced slabs, which are harder and more enduring than the slabby sandstone. This slabby porphyry composes the surface of most of Big Hill, Bear Mountain, Snaggy Ridge, and Mount Newman. Although it is at present only locally used, the rock might find a profitable market as flag, curb, and culvert stones if transportation facilities were available.

SLATE ROCK

Sericite slate, or fine schistose arkose, of light-gray to purple and dark-gray colors, occurs in the Loudoun formation throughout this area. A quarry was opened in this rock on the east slope of Piney Mountain near the north edge of the Fairfield quadrangle by the Pine Grove Mining Co., and a railroad spur connected it with the company's branch line at Pine Grove. The slate is of fine grain and pleasing color but is soft and too finely fissile for roofing. It was later used for making light-colored brick by the Pine Grove Mining Co. Another outcrop of the same formation on the lower east slope of East Big Flat Ridge at the head of Mountain Creek was prospected for slate by William A. Martin, of Gettysburg. The rock exposed in the quarry is equally poor for roofing, as it splits into thin papery layers.

Fine even-grained sericite slate occurs in the outlier of Loudoun formation south of Jacks Mountain station, chiefly south of the Fairfield quadrangle. Here the rock at the surface is firm and splits evenly but with a rough surface. It is possible that the deeper rock may be solid enough to quarry in slabs for mill stock.

Sericite schist has been opened for slate by a tunnel just east of Mount Hope. The schist is a narrow band of altered volcanic rock at the east contact of the greenstone and is probably the result of intense metamorphism by compression and shearing. The slate obtained is light gray and of fine grain and has a good cleavage with firm, smooth surface. It apparently will not make good roofing slate but appears to be satisfactory for mill stock.

ORNAMENTAL STONE

The rocks here referred to as of possible value as ornamental stone are so described because of their attractive coloring and fineness of grain, which permits a high polish. Up to the present time they have been quarried for other purposes on a small scale by blasting with dynamite, which badly shatters the rock. To determine the possible commercial value of any of these ornamental stones it is necessary first to ascertain whether the particular kind of rock can be obtained in masses large enough for the desired purpose. Even if large masses can not be obtained, some of the rock here described, especially greenstone finely speckled with green epidote and red jasper or blotched with burnt-orange spots and altered amygdaloidal rhyolite of pleasing color and design, may be of value in the manufacture of jewelry, as small fragments of attractive appearance can be cut and polished for use in cuff links, watch fobs, stick pins, brooches, lavalieres, necklaces, and similar articles. (See pls. 25, 29, 31–33, and 36.)

Among the great variety of rocks in the pre-Cambrian altered rhyolite and basalt lavas, technically known as metarhyolite and metabasalt, of South Mountain, some have colors and textures that make them desirable ornamental stones. Much of the metarhyolite is dense and fine grained, so that it will take a good polish, and is not too hard to be economically quarried or worked. The more common variety, a dense sheared rhyolite of dull-gray color more or less banded or striped, which forms most of Big Hill and Bear Mountain, is not of attractive appearance. Dark-purple to drab metarhyolite porphyry with scattered white or cream-colored feldspar phenocrysts, which occurs in many places throughout the metarhyolite area and is particularly plentiful on Snaggy Ridge, is a more attractive rock and has some resemblance to the noted porphyry of Egypt extensively used by the ancients for ornamental stone. It is particularly well suited for pedestals or basal parts of monuments on which lighter-colored stone may be mounted, but it also makes a satisfactory stone for carved inscriptions, as the cut lettering is light gray in contrast with the dark background. This rock can no doubt be quarried in large masses of tabular form for monumental use.

Other rhyolite rocks more attractive for ornamental stone are a reddish-purple porphyry specked with white feldspar phenocrysts, obtainable on Corls Ridge near the South Mountain Sanatorium; a bright-red banded dense felsitic rock that occurs at several places in Buchanan Valley south and southwest of Boyd School; a purple rock banded with green epidote near Piney Mountain; and other bright-colored metarhyolites with light bands or streaks on Corls Ridge. The extent and thickness of the layers of these rarer varieties of metarhyolite have not been determined. Some of the more attractive of these ornamental stones are shown in natural colors in a report on Adams County recently published by the Pennsylvania Geological Survey.

A breccia of angular dark-red felsitic rhyolite fragments in a lighter matrix occurring in a metarhyolite outcrop 2 miles east of the South Mountain Sanatorium makes a beautiful polished slab and is worth quarrying for ornamental stone if it can be obtained in suitable masses.

One of the most attractive ornamental rocks in the area is an altered rhyolite found in the new open cut of the National copper prospect (old Bingham mine), 1 mile north of Gladhill station. Its color is mottled light gray and pale pink, splotched with white and bright green in endless variety of tints. A mottled green rock with large round amygdules of a delicate pink material with a bright-green center may appropriately be called "cat's-eye" rock. (See pl. 33.) Some of the green rock is splotched with bright orange. It is of unusually fine, even grain, so that it takes a high polish. The fresh rock on the old mine dump is so shattered by blasting that it is difficult to judge whether slabs and masses of sufficient size for commercial use can be quarried, but even if only small blocks can be obtained the stone may be used for small articles like clock cases, tops of stands and tables, paper weights, ash trays, and possibly jewelry.

The metabasalt also contains rock of pleasing color and fine grain which can be highly polished. One variety is a light-green epidote rock finely mottled with dark green and gray and blotched with reddish-yellow spots; another is dark gray with light-green spots and minute bright-red specks. These occur at many places in the pre-Cambrian greenstone areas of South Mountain, but specimens that have been tested by polishing were collected from the railroad cut southeast of Gladhill station and from the old Reed Hill copper mine, at the head of Copper Run. Small pieces that are especially attractive might be cut into stones for jewelry. Light-green epidote rock with small flecks of native copper that resemble gold when polished are also attractive, but the copper quickly tarnishes and becomes dull.

Diabase from several of the quarries near Gettysburg has been dressed and worked for tombstones and monuments, and some has been polished for this purpose, but the polished stone is rather dark and unattractive. Diabase from McKee Knob, near Fairfield, and from Fox Hill, east of Cashtown, is more attractive for ornamental use, being of lighter shade and of a pinkish hue owing to the presence of pink feldspar. This stone also is illustrated in natural colors in the Adams County report of the Pennsylvania Geological Survey.

Fine-grained milk-white marble of good quality for polishing occurs in several of the quarries around Bittinger, but it is at present burned for lime. Some of the limestone that underlies the Triassic red sandstone along its eastern margin is tinted a delicate pink and buff, and in the quarries east of Irishtown very pretty banded marble of this kind has been taken out, but this also is burned for lime. It takes a good polish, but as the beds are vertical and the pink color probably does not extend down more than a few feet, the amount of suitable marble is too small to be of commercial value. Triassic limestone-conglomerate marble quarried at Point of Rocks, Md., has been used for interior decoration, marble columns, and table tops under the name "calico marble" or "Potomac marble." The marble columns in Statuary Hall in the Capitol at Washington are a notable example of the use of this rock. Its effect is unique but not very pleasing, and the stone is not now popular for ornamental use. Rock of the same kind occurs near Fairfield.

OIL AND COAL

A well was drilled for oil several years ago near the head of Little Marsh Creek, in South Mountain. Nothing could be learned about the result of the boring, but the fact that the well was located in the pre-Cambrian volcanic rocks is sufficient to warrant the statement that no oil or gas was struck. If the well had been sunk in the red Triassic shales or the Paleozoic limestones, this statement could not be so positively made, but there is little probability of finding oil in paying quantities in any of the rocks in the area.

A thin bed of coal was reported to have been found in the red Triassic sandstone at Aspers. The reported opening had not been preserved, nor had samples of the coal been kept. Although commercial deposits of coal occur in Triassic rocks in Virginia and North Carolina, no indications of coal were observed in these rocks in this area, and there is no possibility that workable beds will be found.

SOILS

The soils in the Fairfield and Gettysburg quadrangles are in general derived directly from the rocks beneath or from those immediately adjacent. Where the rocks are deeply mantled by alluvium or terrace gravel along the major streams the soils are independent of the underlying rocks. The land along the east foot of South Mountain is largely covered by mountain wash which resembles the terrace deposits but is more bouldery.

The alluvium and terrace soils, where not too stony, are light, loose, and generally rich and make excellent farm land. They are located in the flat bottoms of the larger streams and on the terraces along their sides, not only where terrace deposits are indicated on the areal-geology maps but also where the alluvial gravel is not thick enough or continuous enough to be mapped or is so mixed with the rock soil as not to be recognized. The more stony soils of mountain wash are well adapted to fruit culture. The soil of the Triassic conglomerate hills from Rocky Grove School (east of Gettysburg) on the south to Wolfpit Hill on the north is very similar to the terrace gravel except that the cobbles and pebbles are inclosed in red sand. It is locally called Chestnut soil, because it is well suited to chestnut tree growth. Like the terrace gravel it makes an excellent fruit soil, and apple culture has been developed to a high degree on it around Biglerville and Arendtsville.

Limestones weather to a deep, rich red or yellow clay soil that yields large crops when not worn out by careless cultivation and neglect of fertilizing. The limestone lowlands around Fairfield and McSherrystown are some of the best farm lands in the area. The larger part of the quadrangles has the red sandy soil derived from red sandstone and shale of the Triassic formations. This soil is light and porous and easily worked but needs much fertilizing, especially lime, and proper rotation of crops to keep it from deteriorating. This part of the area is all cleared and cultivated except some of the steeper slopes adjacent to streams. The diabase areas have a deep, rich clay soil, except on the higher knobs and steep stream slopes, where rock outcrops abound, and these are not cultivated but forested. The schist hills in the southeast corner of the Gettysburg quadrangle have a fair soil of yellow clay which contains many shale fragments, especially on the steeper slopes. The Pigeon Hills have a rocky sandy soil which is heavily forested, like the sandstone ridges of South Mountain.

Forests cover large portions of South Mountain, especially the ridges and slopes composed of Cambrian quartzite, on which the soil is loose sand with many rock fragments and ledges. The forest comprises several varieties of oak, chestnut, birch, gum, and maple, with hemlock and white pine along the watercourses. The original forest growth has been entirely cut off, and the mountains are grown up with various saplings, scrub oak, jack pine, and brush, but much of this waste mountain land has been recently included in the State forest and is now being planted with white pine, protected from fire, and otherwise improved as forest land.

Some of the mountain land composed of the pre-Cambrian volcanic rocks is similarly rugged and forest clad, particularly Big Hill, Bear Mountain, and Snaggy Ridge, which consist of hard slabby rhyolite that disintegrates slowly into thin soil with many large rock slabs and has many angular outcrops of bedrock. In other parts of the volcanic area the flat valley bottoms, gentle slopes, and level uplands are largely cleared and cultivated. The soil of rhyolite areas is generally stony, porous, and poor, but the soil of level areas of greenstone, where the rock is thoroughly weathered and decomposed, is deep and fertile and makes good farm land. The upland around the South Mountain Sanatorium, although on rhyolite, is the largest inhabited and cultivated portion of the mountain area because it is so level, but the soil is poor and farming is unremunerative except truck gardening for the local demand.

WATER RESOURCES

SURFACE WATERS

In South Mountain there are numerous perennial streams fed by springs. In the large Triassic area most of the streams are small, and many dry up in summer, only the larger streams that head in the mountains maintaining a considerable flow. Conewago, Bermudian, Marsh, Middle, and Rock Creeks generally have ample supplies of water throughout the year and are used for city water supplies and for water power by small mills. They can not be depended on for water power in summer, however, except close to or within the mountains.

SPRINGS

There are many good springs in the mountains, some of which have become the centers of summer resorts. Most of the large springs are in the Cambrian quartzite or at its contact with older rocks, and the water is a freestone water, clear, limpid, and soft—that is, free from dissolved salts. Caledonia Springs, 3 miles east of the South Mountain Sanatorium, was formerly a popular resort. About 2½ miles west of the sanatorium, at the foot of the mountain, the springs at Montalto Park have long been the resort of summer visitors and have also been used for medicinal purposes. They are now utilized by the State Forest School, the village of Montalto, and the South Mountain Sanatorium.

At Graefenburg Inn, on the Chambersburg pike near Caledonia Park, there is a perennial spring which attracts many summer guests to the hotel. The spring issues from a quartzite ledge on the property. Several excellent springs issue from the quartzite in the hollows on the east side of Big Pine Flat Ridge but are at present unused. In the limestone area about Fairfield springs have determined the location of many of the farm houses. This water is generally pure but hard from dissolved calcium carbonate. Water cress generally abounds along streams which issue from such springs.

The water from a spring in the red sandstone 1 mile west of Gettysburg is used for medicinal purposes in a sanitarium on the grounds. This water, which has been put on the market as the Gettysburg Katalysine water, has been analyzed by F. A. Genth, and its composition as stated by the company but converted into parts per million is as follows:

Analysis of Gettysburg Katalysine water

[F. A. Genth, analyst]

	Parts per million		Parts per million
Organic matter	12	SO_4	133
Suspended matter	19	Cl	6.8
SiO_2	35	F	.09
Al	Trace.	PO_4	.10
Ca	74	B_4O_7	.48
Mg	25	Ba	Trace.
Na	21	Li	Trace.
K	1.6		556
HCO_3	228		

According to this analysis the water is high in mineral content and of the calcium carbonate type. Rather large amounts of magnesium and of the sulphate radicle are present. The amounts of barium, lithium, fluorine, borate, and phosphate reported are not sufficient to give the water distinct medicinal properties.

A large sulphur spring in the northeast corner of the Gettysburg quadrangle, near Bermudian Churches, was once a health resort said to have been patronized by the early settlers.

In the Gettysburg battlefield there are several small springs that became noted in the great battle. Spanglers Spring, southeast of Culps Hill, is particularly historic, for here Union and Confederate soldiers met under a recognized truce to quench their thirst.

WELLS

The precipitation in this area is heavy, and the water supply in shallow wells is adequate for all purposes during most of the year. In very dry seasons, however, the water gets low in many wells in the Triassic shale areas. Four 8-inch wells were drilled by the United States Government in the Triassic shale in the Gettysburg battlefield for the encampment of the Grand Army of the Republic in 1913. The wells were 342, 350, 430, and 500 feet deep, and their yields ranged from 74 to 215 gallons a minute, which was ample for the large transient gathering.

Springs are generally so plentiful in the mountains that not many wells are needed. In the broad areas of pre-Cambrian rock, however, springs are not so plentiful. A well drilled by the State authorities in hard metarhyolite at the South Mountain Sanatorium to a depth of 500 feet failed to get an adequate supply of water and was abandoned. Wells drilled in greenstone areas may be expected to obtain a fair quantity of good water as they have at the summer resorts of Charmian and Monterey, just southwest of Gladhill.

RAIN-WATER CISTERNS

In areas where the supply of shallow-well water is uncertain, rain water is caught in cisterns and used not only for stock and washing clothes but also for general domestic purposes and even for drinking. Where large cement cisterns are constructed and the pipes are so arranged that the first fall of rain is allowed to carry away the dust and impurities on the roof and in the pipes before the water is turned into the cistern, rain water is not unhealthful or unpleasant for domestic use, and the supply is always adequate. Rain water that is conducted from the eaves through rusty, unclean troughs or pipes to a wooden cistern which is seldom cleaned out is unfit for drinking and is a means of harboring and spreading disease.

PUBLIC SUPPLIES

The cities and principal villages of the area have waterworks, but most of them do not have proper sewer systems.

Gettysburg, the largest city in the area, obtains its water supply from Marsh Creek, which heads in South Mountain. The water is pure and soft, being derived from springs in the siliceous mountain rocks, and the supply is adequate for all purposes throughout the year. The water is diverted from the creek at the pumping station 4 miles west of the city and is forced directly into the mains. A reservoir on Cemetery Hill, maintained for fire protection and emergency, is supplied by water from windmills that pump from two deep wells in the vicinity.

Biglerville has a reservoir, fed by springs, in the hills about 1 mile northwest of the town, which furnishes an adequate supply of pure freestone water by gravity for domestic purposes and fire protection. Arendtsville is supplied by a reservoir on the hill west of the town, fed by water piped across the valley from several springs in the hill north of Clearspring School. The water flows by gravity, which gives adequate pressure for fire protection. Bendersville has a small reservoir at a spring on the mountain side 1½ miles southwest of the town. The water flows by gravity and is used for domestic purposes and fire protection. Cashtown gets its water supply from a spring west of the village and south of the pike, which probably issues from the rhyolite at or near a fault. The water is piped to the village from a small reservoir at the spring.

The South Mountain Sanatorium, which houses several thousand people, has until recently depended for its supply on a spring on the mountain slope to the south, where a small reservoir was built. During the drought of 1908 and 1909, however, the supply ran so low that water from a near-by creek had to be pumped into the water system. An 8-inch well was also drilled but failed to obtain a supply of water. An auxiliary water supply has since been added from the springs at the head of West Branch of Antietam Creek, in Montalto Park, at the west foot of the mountain, where an ample supply of good water was obtained. This supply is in part raised by pumps 679 feet to the reservoir at the springs back of the sanatorium, where there is a filter plant, and in part is pumped to a tank on top of Rocky Mountain, 55 feet higher, for fire protection.

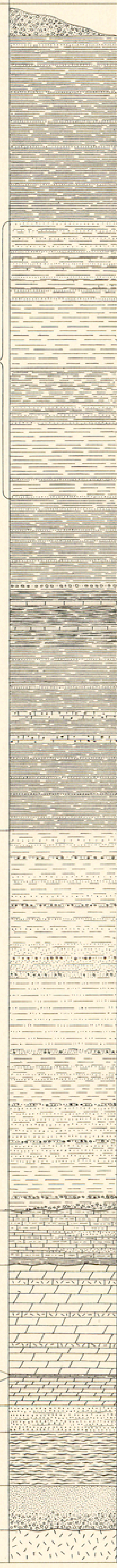
Fairfield depends chiefly on individual wells about 15 feet deep for its water supply, the water probably being the underflow of Spring Run and Middle Creek. At the Catholic Church, however, where there was formerly a cemetery, a well was sunk to a depth of 173 feet, largely in limestone. The last 50 feet was reported to be in part flint, which may possibly have been hard Cambrian sandstone, for a large quantity of freestone water was obtained that is reported to rise within 15 feet of the surface.

Midway and McSherrystown get part of their water supply from the Pigeon Hills, where the Hanover & McSherrystown Water Co. has three reservoirs supplied by the Gitts Springs. These springs issue from the contact of the basal Cambrian quartzite on greenstone. A well has been drilled 424 feet into the pre-Cambrian greenstone and slate to increase the flow but with little success. A standpipe in McSherrystown gives additional protection from fire.

COLUMNAR SECTIONS

GENERALIZED SECTION OF ROCKS SOUTHEAST OF SOUTH MOUNTAIN, FAIRFIELD AND GETTYSBURG QUADRANGLES.

SCALE: 1 INCH=2000 FEET.

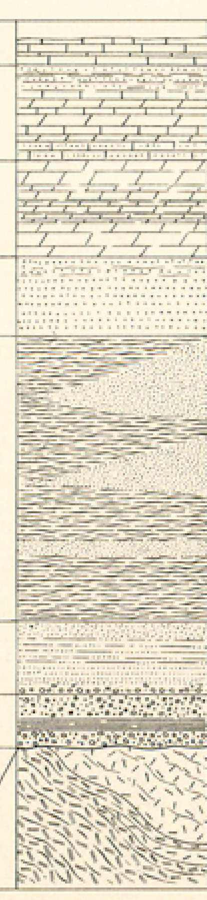


System		Formation Name	Symbol	Columnar Section	Thickness in Feet	Character of Rocks	Character of Topography and Soils
TRIASSIC	UPPER TRIASSIC (NEWARK GROUP)	(Arendtsville conglomerate lentil.)	(Ŧa)		(0-500)	Coarse unconsolidated quartzose conglomerate in red sand matrix, Ŧa, replaced to south by limestone conglomerate cemented by red calcareous matrix.	The quartzose conglomerate forms high hills adjacent to the mountains; the limestone conglomerate forms lowlands with few outcrops.
		Gettysburg shale.	Ŧg			Chiefly soft red shale and sandstone.	
		(Heidlersburg member.)	Ŧh			Red shale and sandstone interbedded with hard gray to white sandstone and a little gray to black shale.	Plains with gentle valleys.
		Gettysburg shale.	Ŧg		16000[1]	Chiefly soft red shale and some red sandstone, locally altered to hard argillite, hornstone, and porcelanite by injection of thick diabase sill.	Plains above which rise low hills and some higher sharp knobs composed of diabase.
		New Oxford formation.	Ŧno		7000[1]	Red shale and sandstone, with some beds of harder light-colored micaceous sandstone. Red shale and sandstone with more numerous beds of hard light-colored micaceous sandstone, arkose, and conglomerate.	Plains with gentle valleys. Low ridge at eastern margin.
		(Quartzose conglomerate member.)	(Ŧnc)			Coarse red quartzose conglomerate locally at base.	
		UNCONFORMITY					
ORDOVICIAN	Lower Ord.	Conestoga limestone.	Oc		1000±	Impure blue argillaceous limestone weathering readily to shaly fragments and soil	Lowland, with few outcrops.
		UNCONFORMITY					
CAMBRIAN	LOWER CAMBRIAN	Ledger dolomite.	Ꞓlg		2000±	Pure coarse gray dolomite and beds of equally pure blue and white limestone marble, which are extensively quarried	Lowland, with few outcrops.
		Kinzers formation.	Ꞓk		50±	Dark argillaceous shale.	Line of low hills in the lowland.
		Vintage dolomite.	Ꞓv		500±	Dark dolomite, poorly exposed.	Lowland, with few outcrops.
		Antietam sandstone.	Ꞓa		500±	Granular sandstone, weathering to porous slabs with rusty fossiliferous partings.	Low hills and mountain slopes.
		Harpers schist.	Ꞓh		1000+	Gray sandy schist.	Mountain slopes and hill country.
		Chickies quartzite with Hellam conglomerate member.	Ꞓc (Ꞓhl)		800±	White vitreous quartzite with scolithus tubes; hard pebbly quartzite and conglomerate of glassy quartz at base, Ꞓhl.	High ridges and mountain tops of Pigeon Hills.
		UNCONFORMITY					
ALGONKIAN		Metabasalt (greenstone.)	Amb		500±	Massive greenstone, amygdaloid, and spotted sericite schist.	Ridges and valleys of Pigeon Hills.

[1] The Triassic sediments overlap progressively westward, so that the thicknesses given here are the total aggregates but are not present at any one place; probably the greatest thickness at any place is not over half the total.

GENERALIZED SECTION OF ROCKS FOR SOUTH MOUNTAIN AREA, FAIRFIELD QUADRANGLE.

SCALE: 1 INCH=2000 FEET.



System		Formation Name	Symbol	Columnar Section	Thickness in Feet	Character of Rocks	Character of Topography and Soils
ORDOVICIAN	LOWER ORD- (?)	Beekmantown (?) limestone. (Intervening formations concealed.)	Ob		300+	Blue limestone, in part banded and earthy, weathering to tripoli.	Lowland with few outcrops.
CAMBRIAN	LOWER AND MIDDLE	Waynesboro formation.	Ꞓw		1000±	Mottled sandstone and purple sandy shale at top, blue white limestone and dolomite in middle, and siliceous gray sandy limestone and sandstone at base.	Low hills in the limestone valley.
		Tomstown dolomite.	Ꞓt		1000±	Coarse glistening gray dolomite, blue limestone, and some shale and sericite schist, poorly exposed.	Valleys.
	LOWER CAMBRIAN	Antietam sandstone.	Ꞓa		800	Coarse quartzose sandstone with numerous scolithus tubes and hard vitreous quartzite with rusty fossiliferous partings.	Mountain slopes and smaller ridges and knobs.
		Harpers schist with Montalto quartzite member.	Ꞓh (Ꞓma)		3000	Dark hackly sandy slate or schist and white quartzite; the quartzite, (Ꞓma), in thin beds at the south, expands northeastward to represent most of the formation. The upper part of the quartzite is filled with scolithus tubes.	High ridges and mountains with sharp valleys on the schist beds.
		Weverton sandstone.	Ꞓw		750	Gray and purplish feldspathic sandstone and quartz conglomerate.	Crests of high ridges and steep mountain slopes.
		Loudoun formation.	Ꞓl		550	Soft purplish arkosic conglomerate and fine sericite slate.	Steep mountain slopes
		UNCONFORMITY					
ALGONKIAN		Metabasalt greenstone.	mb		1000±	Massive to schistose greenstone and bluish gray rocks containing epidote and quartz; altered basalt lava.	Mountains and ridges, rounded knobs, and open intermontane valleys.
		Aporhyolite.	ar		1000±	Bluish gray to pink and purplish felsite with white phenocrysts, altered rhyolite lava, white to red sericite schist in upper part and red breccia and tuff at top.	

TOPOGRAPHY

STATE OF PENNSYLVANIA
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DEPARTMENT OF THE INTERIOR
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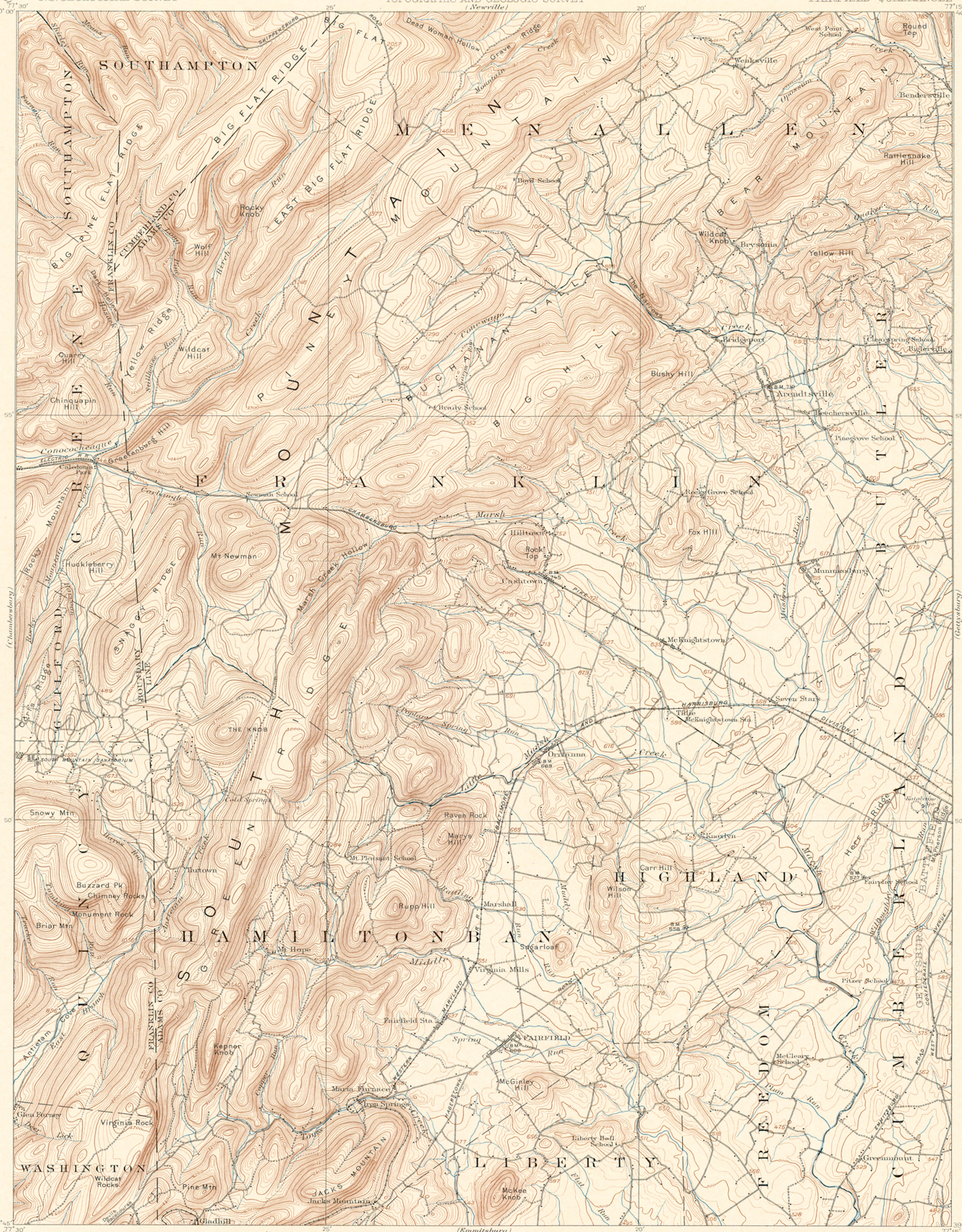
PENNSYLVANIA
FAIRFIELD QUADRANGLE



EXPLANATION

RELIEF
printed in brown

Altitude
above mean sea level instrumentally determined

Contours
(showing height above sea, horizontal form, and steepness of slope of the surface)

DRAINAGE
printed in blue

Streams

Intermittent streams

Pond

Springs

CULTURE
printed in black

Roads and buildings

Church or schoolhouse and cemetery

Private or poor roads

Trail

Railroad

Electric railroad

Bridge

County line

State township line

City, village, or borough line

Triangulation or primary traverse monument

Bench mark giving precise altitude

R.B. Marshall, Chief Geographer.
Frank Sutton, Geographer in charge.
Topography by Hersey Munroe and Second Geol. Survey of Pennsylvania (A.E. Lehman.)
Control by Geo. T. Hawkins and H.M. Gillman, Jr.
Surveyed in 1885 and 1908.
SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA

APPROXIMATE MEAN DECLINATION 1929

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.

Edition of Dec. 1909, reprinted 1929.
Polyconic projection. North American datum.

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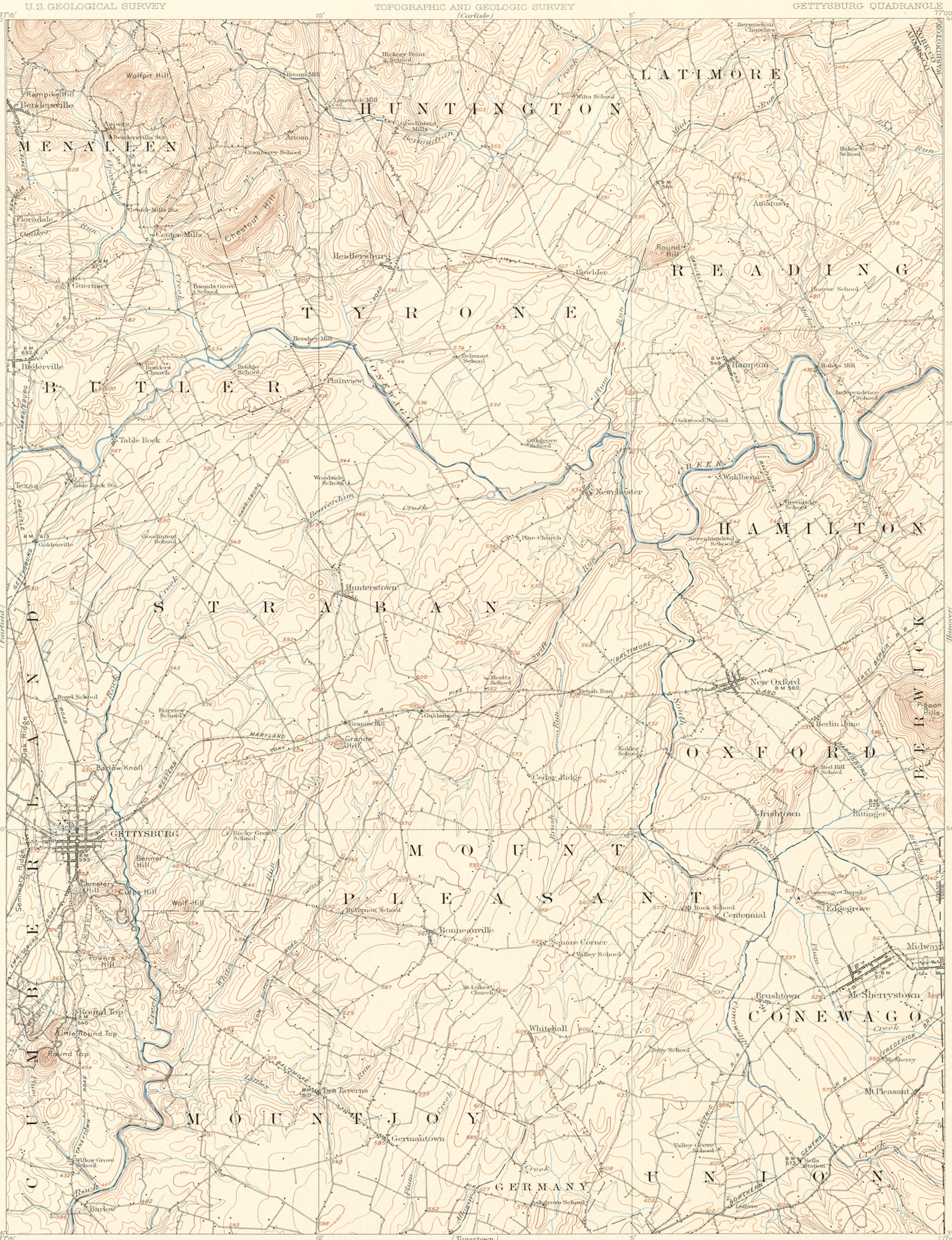

EXPLANATION

RELIEF *printed in brown*

Altitude *above mean sea level instrumentally determined*

Contours *(showing height above sea, horizontal form, and steepness of slope of the surface)*

DRAINAGE *printed in blue*

Streams

Intermittent stream

CULTURE *printed in black*

Roads and buildings

Church or schoolhouse and cemetery

Private or poor roads

Railroad

Electric railroad

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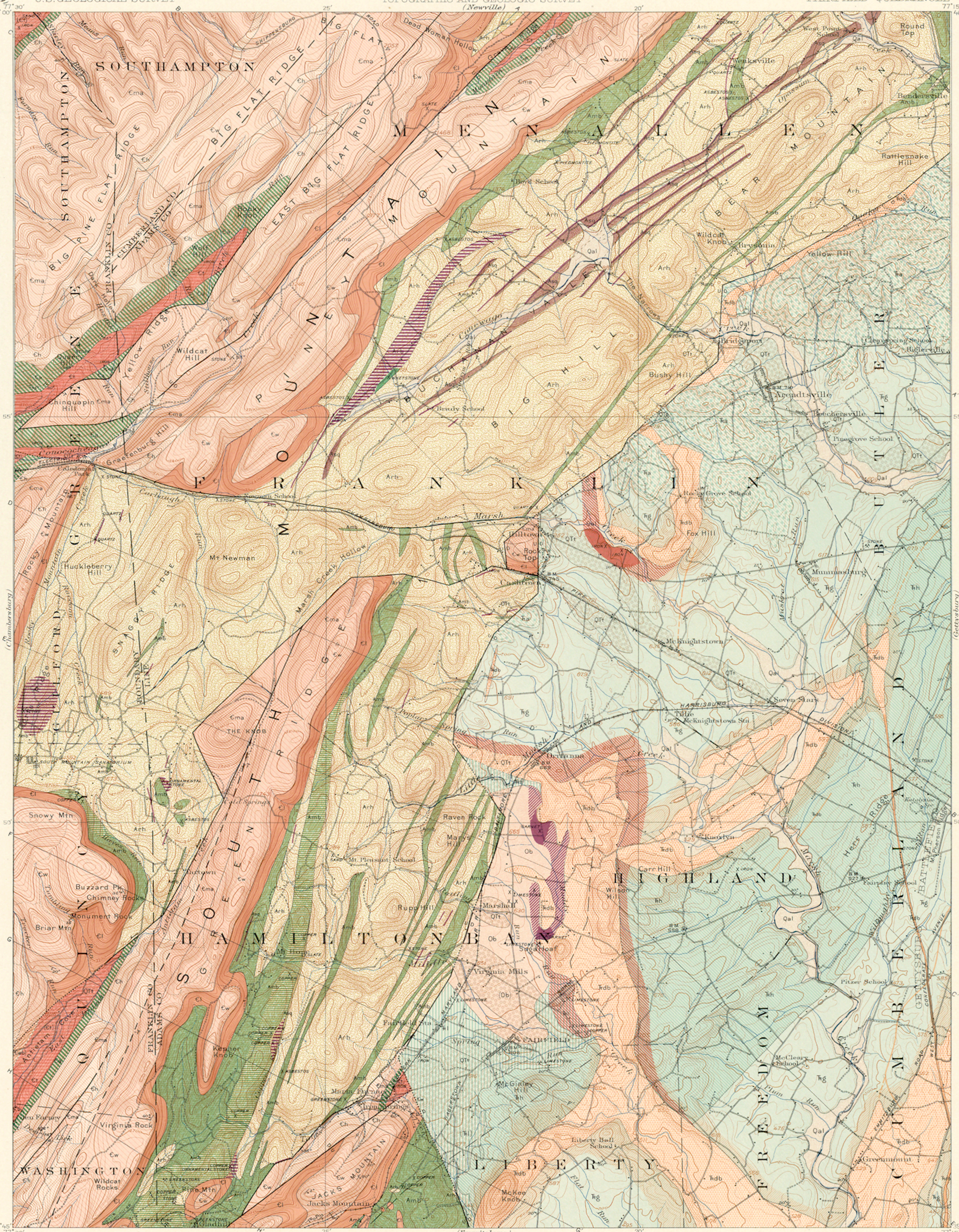
PENNSYLVANIA
FAIRFIELD QUADRANGLE



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Edition of Feb. 1929.

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Surveyed in 1908-1925.

EXPLANATION

SEDIMENTARY ROCKS

(subaqueous deposits shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles)

QUATERNARY — Recent

Qal — **Alluvium** *(gravel and silt in stream bottoms; only larger areas mapped)*

TERTIARY (?) — Pliocene (?) and Pleistocene

QTt — **Terrace gravel and alluvial cones** *(gravel, cobbles, and sand on elevated terraces and benches along the larger streams and at the mouths of steep mountain streams)*

UNCONFORMITY

TRIASSIC — Upper Triassic (Newark group)

Ꞧl, Ꞧa, Ꞧh, Ꞧg — **Gettysburg shale** *(chiefly red shale and soft red sandstone; middle part, Heidlersburg member, Ꞧh, contains numerous harder white sandstone beds; Arendtsville fanglomerate lentil, unassorted fragments of quartzite and metarhyolite, Ꞧa, and limestone conglomerate lentil, Ꞧl, at the top in places; shale adjacent to intrusive diabase metamorphosed to hard dense dark-purple and black argillite, and red sandstone altered to hard white sandstone, shown by red ruling)*

UNCONFORMITY

ORDOVICIAN — Lower (?) Ordovician — East of South Mountain

Ob — **Beekmantown (?) limestone** *(dolomite, impure laminated blue limestone, marble, and earthy gray limestone; may include some unseparated Conococheague or Elbrook limestone of Cambrian age)*

INTERVENING FORMATIONS CONCEALED

CAMBRIAN — West of South Mountain

Lower and Middle (?) Cambrian

Ꞓwb — **Waynesboro formation** *(gray sandstone, dolomite, limestone, and purple sandy shale)*

Lower Cambrian

Ꞓt — **Tomstown dolomite** *(coarse gray dolomite, blue limestone, and shale)*

Ꞓa — **Antietam sandstone** *(white scolithus-bearing sandstone and vitreous quartzite; rusty banded fossiliferous beds at top)*

Ꞓh, Ꞓma — **Harpers schist with Montalto quartzite member, Ꞓma** *(white quartzite containing scolithus tubes interbedded with dark sandy slate and fissile schist or phyllite; chiefly quartzite at north)*

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Ꞓl — **Loudoun formation** *(soft purplish arkosic sandstone and conglomerate and dark banded sericite schist)*

UNCONFORMITY

METAMORPHOSED VOLCANIC ROCKS

(shown by patterns of triangles, rhombs, and hachures)

ALGONKIAN

Amb — **Metabasalt** *(basalt flows, altered to schistose greenstone and epidote rock)*

Arb — **Rhyolitic breccia** *(volcanic fragmental material, chiefly coarse but includes some fine whetstone)*

Arh — **Aporhyolite** *(rhyolite flows altered to purplish felsitic rock)*

Asq — **Sericite schist and vein quartz** *(white, greenish, and red fine-grained schist, probably altered tuff; called "soapstone")*

IGNEOUS ROCKS

(shown by patterns of triangles and rhombs)

LATE TRIASSIC — Intrusive into Triassic sediments and older rocks

Ꞧdb — **Diabase** *(sills, irregular intrusive masses, and dikes)*

Faults *(dotted where concealed)*

T *Overthrust side of thrust fault*
Direction of movement of shear fault
D *Downthrown side of normal fault*
U *Upthrown side of normal fault*
Strike and dip of stratified rocks
Strike of vertical bed
Strike and overturned dip

⚒ *Quarries and mines*
× *Prospects and abandoned quarries and mines*

ECONOMIC DATA

Magnetite *(solid color, area in which magnetite has been mined; ruled pattern, area in which magnetite may occur at depth)*

Brown iron ore, white paper clay, and building sand *(area in which deposits of these materials probably occur)*

Building sand and quartzite building stone *(area in which deposits of these materials occur)*

Greenstone and copper *(granulated greenstone is used in manufacture of artificial slate; ruled area is copper-bearing and has been prospected for copper)*

Garnet abrasive *(solid color, area in which considerable garnet occurs; ruled pattern, area in which garnet may occur)*

Vein quartz *(only the more prominent veins mapped; the best rock has been used for tiles and pottery)*

Sericite schist *(probably suitable for brick clay and possibly for paper clay and slate; also a possible source of potash)*

Diabase foundation stone *(area in which foundation stone, road material, and possibly building stone may be obtained)*

Monumental stone and arts-and-crafts jewelry stone *(altered rhyolite and basalt of pleasing color and fine grain, which take a high polish)*

Whetstone *(fine siliceous rhyolitic tuff, used for whetstones)*

ECONOMIC GEOLOGY

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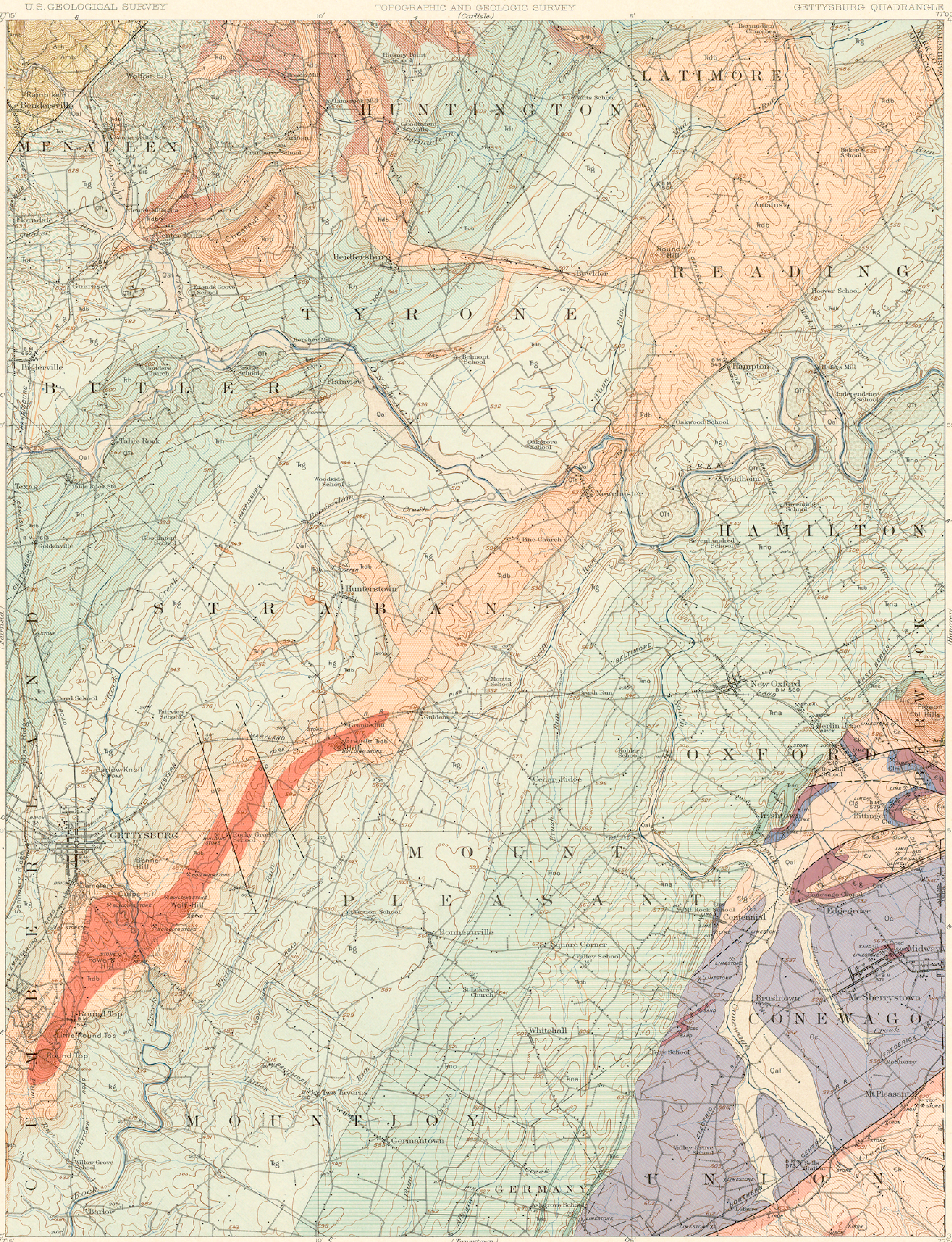
PENNSYLVANIA
GETTYSBURG QUADRANGLE



EXPLANATION

SEDIMENTARY ROCKS

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QUATERNARY — Recent

Qal — **Alluvium** (gravel and silt in stream bottoms; only larger areas mapped)

TERTIARY (?) — Pliocene (?) and Pleistocene

QTt — **Terrace gravel** (gravel, cobbles, and sand on elevated terraces and benches along the larger streams)

UNCONFORMITY

TRIASSIC — Upper Triassic (Newark group)

Ŧg, Ŧh, Ŧa — **Gettysburg shale** (chiefly red shale and soft red sandstone; middle part, Heidlersburg member, Ŧh, contains numerous harder white sandstone beds; Arendtsville fanglomerate lentil, unassorted fragments of quartzite and metarhyolite, Ŧa, at the top in places; shale adjacent to intrusive diabase metamorphosed to hard dense dark-purple and black argillite, and red sandstone altered to hard white sandstone, shown by red ruling)

Ŧno, Ŧna, Ŧnc — **New Oxford formation** (red shale and sandstone with beds of hard light-colored micaceous sandstone and conglomerate, lower part, Ŧna, containing many interbedded layers of light-colored, micaceous arkose, and thin beds of quartzose conglomerate, Ŧnc)

UNCONFORMITY

ORDOVICIAN — Lower (?) Ordovician

Oc, Ocsd, Ocs — **Conestoga limestone** (thin-bedded, impure, blue limestone; dark argillaceous shale and earthy gray sandstone, Ocs, at base; sandy beds weathering to sand, Ocsd)

UNCONFORMITY

CAMBRIAN — Lower Cambrian

Probably equivalent to Tomstown dolomite:

€lg, €lm — **Ledger dolomite** (coarse gray pure dolomite, with pure white and blue limestone marble, €lm, in places)

€k — **Kinzers formation** (chiefly gray shale)

€v — **Vintage dolomite** (dark impure dolomite)

€a — **Antietam sandstone** (rusty banded fossiliferous sandstone, weathering porous)

€h — **Harpers schist** (gray sandy schist and buff-weathering slate)

€c, €hl — **Chickies quartzite with Hellam conglomerate member, €hl** (vitreous, white, scolithus-bearing quartzite, with basal conglomerate, €hl, of glassy quartz pebbles and grains)

UNCONFORMITY

METAMORPHOSED VOLCANIC ROCKS

(shown by patterns of triangles, rhombs, and hachures)

ALGONKIAN

Amb — **Metabasalt** (basalt flows altered to greenstone)

Arh — **Aporhyolite** (rhyolite flows altered to purplish felsitic rock)

IGNEOUS ROCKS

(shown by patterns of triangles and rhombs)

LATE TRIASSIC — Intrusive into Triassic sediments and older rocks

Ŧb, Ŧdb — **Diabase** (sills, intrusive masses, and dikes; one small basalt lava flow, Ŧb, interbedded in upper part of Heidlersburg member of Gettysburg shale near Bendersville)

Faults (dotted where concealed)

T Overthrust side of thrust fault
D Down-dropped side of normal fault
U Up-thrown side of normal fault
Strike and dip of stratified rocks

⚒ *Quarries and mines*
X *Prospects and abandoned quarries and mines*

ECONOMIC DATA

Diabase building stone (areas in which stone for buildings, steps, culverts, curbstones, monument stones, crushed stone, and road material is quarried)

Diabase foundation stone (area in which stone suitable for foundation stone, crushed stone, road material, and possibly building stone occur)

Magnetite (areas in which magnetite iron ore may occur at depth)

Brown iron ore (area in which ore has been mined)

Pure limestone (area in which high-calcium limestone occurs and has been quarried for finishing lime, chemical lime, and agricultural lime, and suitable also for cement manufacture; interbedded impure limestone is crushed for broken stone and road material and is also suitable for foundation stone)

Impure limestone (area in which limestone is quarried for foundation stone, broken stone, road material, and fertilizer lime, and the surficial residual clay is suitable for brick manufacture)

Marble (variegated pink and buff marble of pleasing color and high polish; fine-grained white marble occurs elsewhere in the pure limestone area)

Building sand (coarse sand derived from weathered sandy limestone quarried for building purposes)

Frank Sutton, Geographer in charge.
Topography by L.C. Fletcher.
Control by S.S. Gannett, Geo. T. Hawkins, and Gettysburg Battlefield Commission.
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TRUE NORTH / MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1929.

Scale $\frac{1}{62500}$

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Contour interval 20 feet.
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Geology by Geo. W. Stose.
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DEPARTMENT OF THE INTERIOR
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AREAL GEOLOGY

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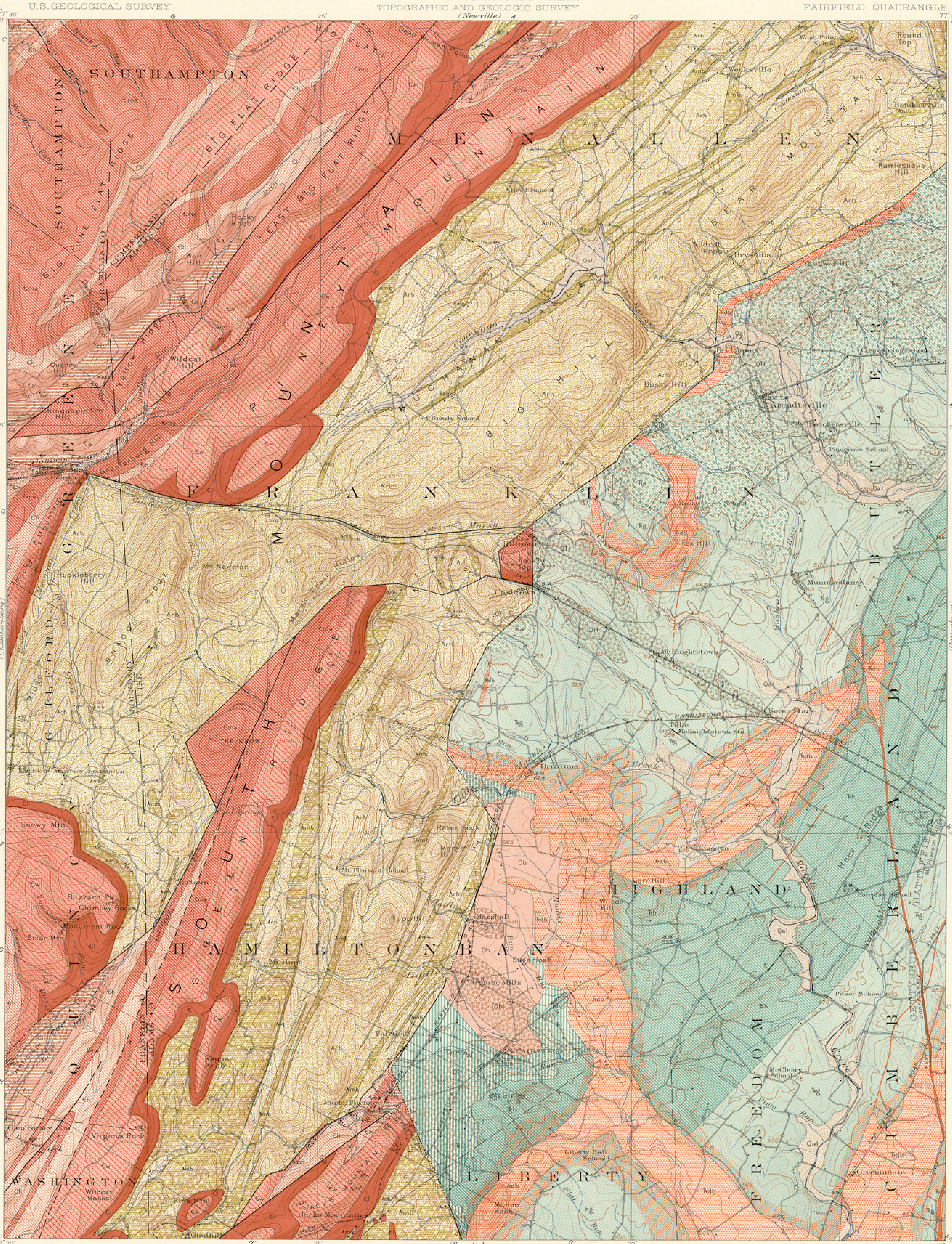

EXPLANATION

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UNCONFORMITY

TRIASSIC — Upper Triassic (Newark group)

Trl, Tra, Trh, Trg — **Gettysburg shale** (chiefly red shale and soft red sandstone; middle part, Heidlersburg member, Trh, contains numerous harder white sandstone beds; Arendtsville fanglomerate lentil, unassorted fragments of quartzite and metarhyolite, Tra, and limestone conglomerate lentil, Trl, at the top in places; shale adjacent to intrusive diabase metamorphosed to hard dense dark-purple and black argillite, and red sandstone altered to hard white sandstone, shown by red ruling)

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IGNEOUS ROCKS

(shown by patterns of triangles and rhombs)

LATE TRIASSIC — Intrusive into Triassic sediments and older rocks

Trdb — **Diabase** (sills, irregular intrusive masses, and dikes)

Faults (dotted where concealed)

- T Overthrust side of thrust fault
- Direction of movement of shear fault
- D Downthrown side of normal fault
- U Upthrown side of normal fault
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- Strike of vertical bed
- Strike and overturned dip

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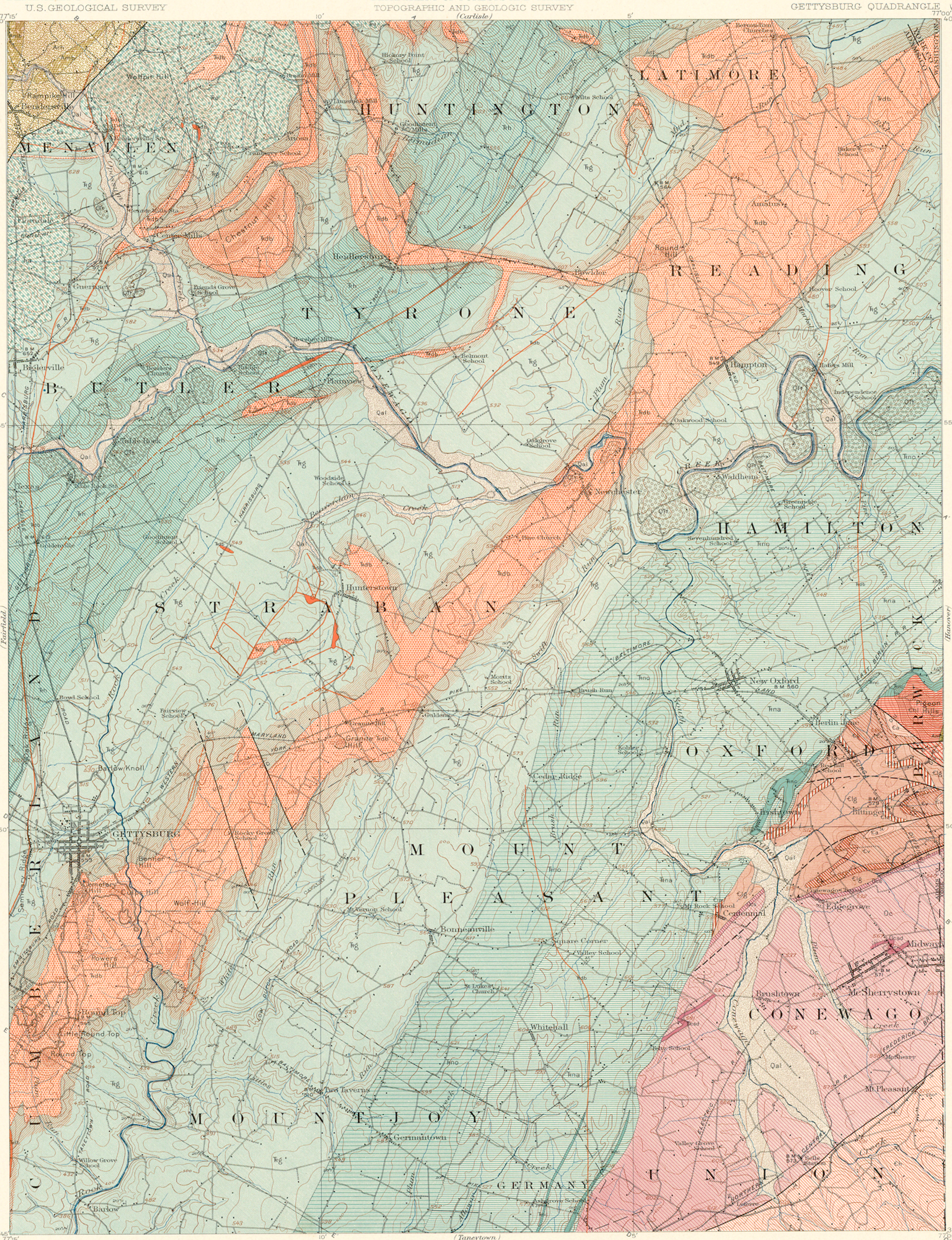

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(vitreous, white, scolithus-bearing quartzite, with basal conglomerate, Ꞓhl, of glassy quartz pebbles and grains)

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(shown by patterns of triangles, rhombs, and hachures)

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(shown by patterns of triangles and rhombs)

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STRUCTURE SECTIONS

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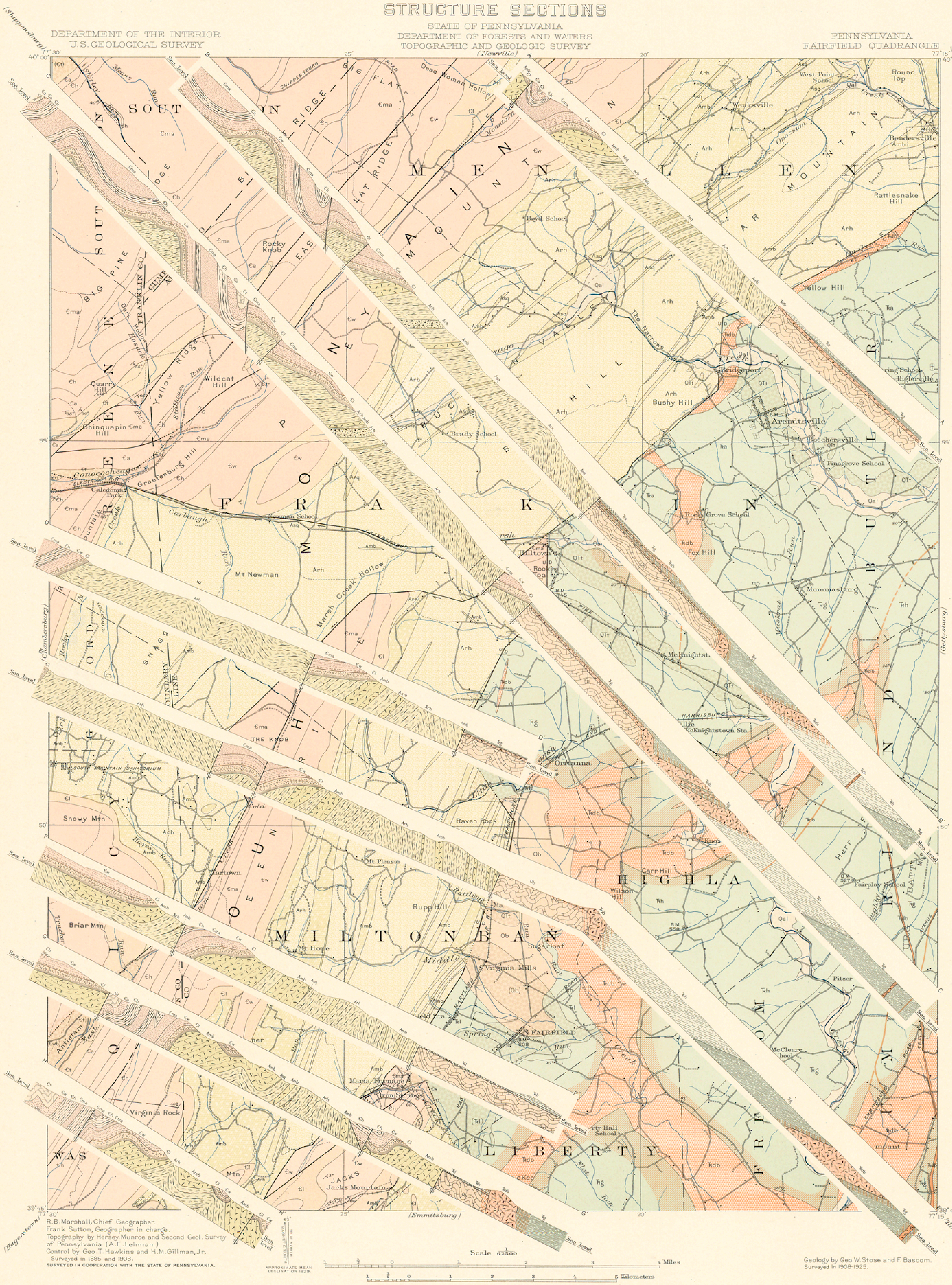

EXPLANATION

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TRIASSIC — Upper Triassic (Newark group)

Ꞧg, Ꞧh, Ꞧl, Ꞧa — **Gettysburg shale**
(chiefly red shale and soft red sandstone; middle part, Heidlersburg member, Ꞧh, contains numerous harder white sandstone beds; Arendtsville fanglomerate lentil, unassorted fragments of quartzite and metarhyolite, Ꞧa, and limestone conglomerate lentil, Ꞧl, at the top in places; shale adjacent to intrusive diabase metamorphosed to hard dense dark-purple and black argillite, and red sandstone altered to hard white sandstone, shown by red ruling)

UNCONFORMITY

ORDOVICIAN — Lower (?) Ordovician — East of South Mountain

Ob — **Beekmantown (?) limestone**
(dolomite, impure laminated blue limestone, marble, and earthy gray limestone; may include some unseparated Conococheague or Elbrook limestone of Cambrian age)

INTERVENING FORMATIONS CONCEALED

CAMBRIAN — Lower and Middle (?) Cambrian — West of South Mountain

Ꞓwb — **Waynesboro formation**
(gray sandstone, dolomite, limestone, and purple sandy shale)

Lower Cambrian

Ꞓt — **Tomstown dolomite**
(coarse gray dolomite, blue limestone, and shale)

Ꞓa — **Antietam sandstone**
(white scolithus-bearing sandstone and vitreous quartzite; rusty banded fossiliferous beds at top)

Ꞓh, Ꞓma — **Harpers schist with Montalto quartzite member, Ꞓma**
(white quartzite containing scolithus tubes interbedded with dark sandy slate and fissile schist or phyllite; chiefly quartzite at north)

Ꞓw — **Weverton sandstone**
(gray and purple feldspathic sandstone and conglomerate)

Ꞓl — **Loudoun formation**
(soft purplish arkosic sandstone and conglomerate and dark banded sericite schist)

UNCONFORMITY

METAMORPHOSED VOLCANIC ROCKS

ALGONKIAN

Amb — **Metabasalt**
(basalt flows, altered to schistose greenstone and epidote rock)

Arb — **Rhyolitic breccia**
(volcanic fragmental material, chiefly coarse but includes some fine whetstone)

Arh — **Aporhyolite**
(rhyolite flows altered to purplish felsitic rock)

Asq — **Sericite schist and vein quartz**
(white, greenish, and red fine-grained schist, probably altered tuff; called "soapstone")

IGNEOUS ROCKS

LATE TRIASSIC — Intrusive into Triassic sediments and older rocks

Ꞧdb — **Diabase**
(sills, irregular intrusive masses, and dikes)

Faults
(dotted where concealed)

- T — *Overthrust side of thrust fault*
- *Direction of movement of shear fault*
- D — *Downthrown side of normal fault*
- U — *Upthrown side of normal fault*
- *Strike and dip of stratified rocks*
- *Strike of vertical bed*
- *Strike and overturned dip*

R.B. Marshall, Chief Geographer.
Frank Sutton, Geographer in charge.
Topography by Hersey Munroe and Second Geol. Survey of Pennsylvania (A.E. Lehman)
Control by Geo. T. Hawkins and H.M. Gillman, Jr.
Surveyed in 1885 and 1908.
SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH — MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1929.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of Feb. 1929.

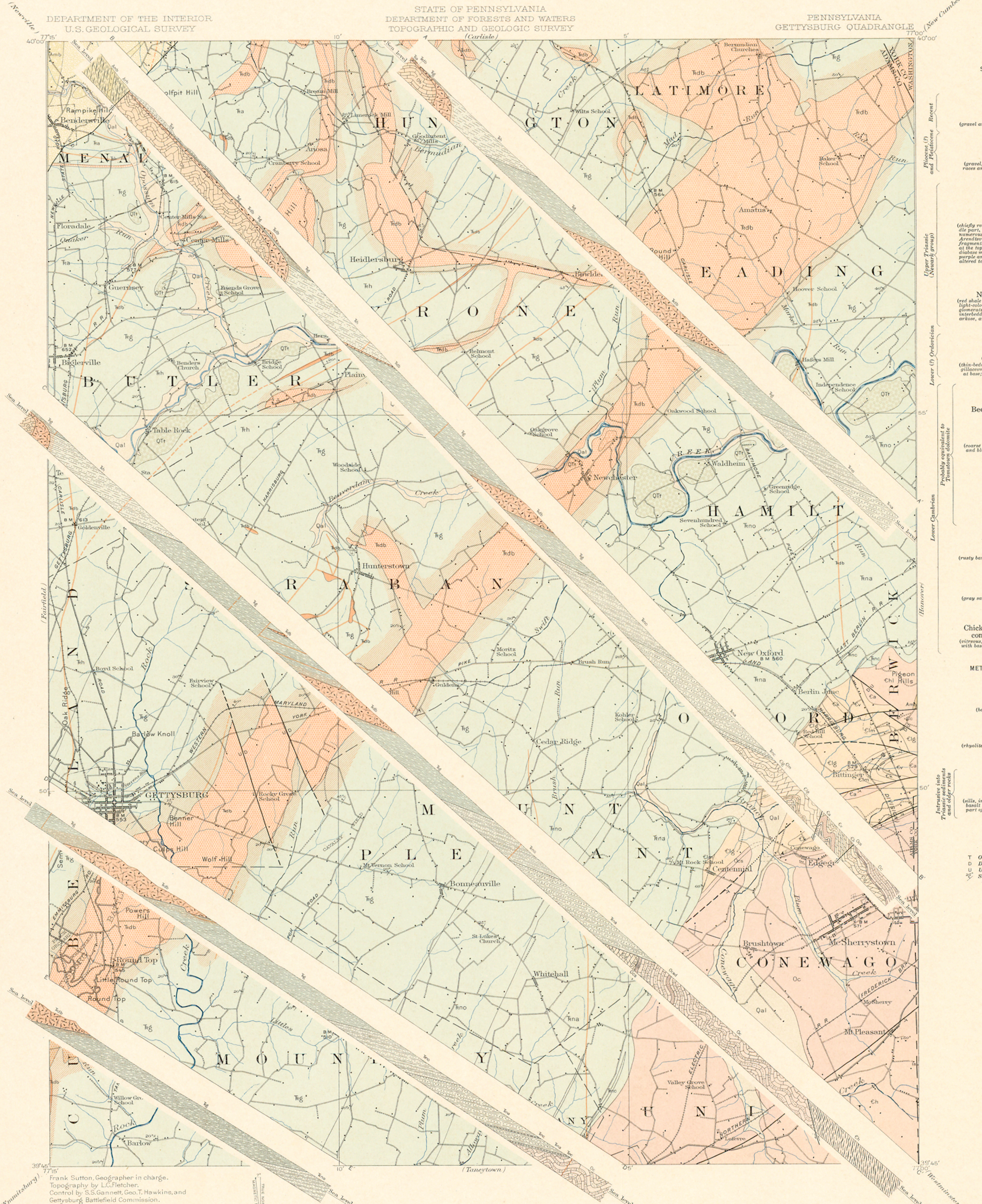
Geology by Geo. W. Stose and F. Bascom.
Surveyed in 1908-1925.

STRUCTURE SECTIONS

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

STATE OF PENNSYLVANIA
DEPARTMENT OF FORESTS AND WATERS
TOPOGRAPHIC AND GEOLOGIC SURVEY

PENNSYLVANIA
GETTYSBURG QUADRANGLE



EXPLANATION

SEDIMENTARY ROCKS

SHEET SYMBOL — SECTION SYMBOL

QUATERNARY — Recent

Qal — **Alluvium** (gravel and silt in stream bottoms; only larger areas mapped)

TERTIARY (?) — Pliocene (?) and Pleistocene

QTt — **Terrace gravel** (gravel, cobbles, and sand on elevated terraces and benches along the larger streams)

UNCONFORMITY

TRIASSIC — Upper Triassic (Newark group)

Ꞓa, Ꞓg, Ꞓh — **Gettysburg shale** (chiefly red shale and soft red sandstone; middle part, Heidlersburg member, Ꞓh, contains numerous harder white sandstone beds; Arendtsville fanglomerate lentil, unassorted fragments of quartzite and metarhyolite, Ꞓa at the top in places; shale adjacent to intrusive diabase metamorphosed to hard dense dark-purple and black argillite, and red sandstone altered to hard white sandstone, shown by red ruling)

Ꞓno, Ꞓna, Ꞓnc — **New Oxford formation** (red shale and sandstone with beds of hard light-colored micaceous sandstone and conglomerate, lower part, Ꞓna, containing many interbedded layers of light-colored, micaceous arkose, and thin beds of quartzose conglomerate, Ꞓnc)

UNCONFORMITY

ORDOVICIAN — Lower (?) Ordovician

Ocsd, Oc, Ocs — **Conestoga limestone** (thin-bedded, impure, blue limestone; dark argillaceous shale and earthy gray sandstone Ocs, at base; sandy beds weathering to sand, Ocsd)

UNCONFORMITY

CAMBRIAN — Lower Cambrian (Probably equivalent to Tomstown dolomite: Ob through Ꞓv)

Ob — **Beekmantown ? limestone**

Ꞓlg, Ꞓlm — **Ledger dolomite** (coarse gray pure dolomite, with pure white and blue limestone marble, Ꞓlm, in places)

Ꞓk — **Kinzers formation** (chiefly gray shale)

Ꞓv — **Vintage dolomite** (dark impure dolomite)

Ꞓa — **Antietam sandstone** (rusty banded fossiliferous sandstone, weathering porous)

Ꞓh — **Harpers schist** (gray sandy schist and buff-weathering slate)

Ꞓc, Ꞓhl — **Chickies quartzite with Hellam conglomerate member, Ꞓhl** (vitreous, white, scolithus-bearing quartzite, with basal conglomerate, Ꞓhl, of glassy quartz pebbles and grains)

UNCONFORMITY

METAMORPHOSED VOLCANIC ROCKS

ALGONKIAN

Amb — **Metabasalt** (basalt flows altered to greenstone)

Arh — **Aporhyolite** (rhyolite flows altered to purplish felsitic rock)

IGNEOUS ROCKS

LATE TRIASSIC — Intrusive into Triassic sediments and older rocks

Ꞓb, Ꞓdb — **Diabase** (sills, intrusive masses, and dikes; one small basalt lava flow, Ꞓb, interbedded in upper part of Heidlersburg member of Gettysburg shale near Bendersville)

Faults (dotted where concealed)

- T Overthrust side of thrust fault
- D Down-dropped side of normal fault
- U Up-thrown side of normal fault
- Strike and dip of stratified rocks

Frank Sutton, Geographer in charge.
Topography by L.C. Fletcher.
Control by S.S. Gannett, Geo. T. Hawkins, and Gettysburg Battlefield Commission.
Surveyed in 1906-1907.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH — MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1929.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of Feb. 1929.

Geology by Geo. W. Stose.
Surveyed in 1908-1925.

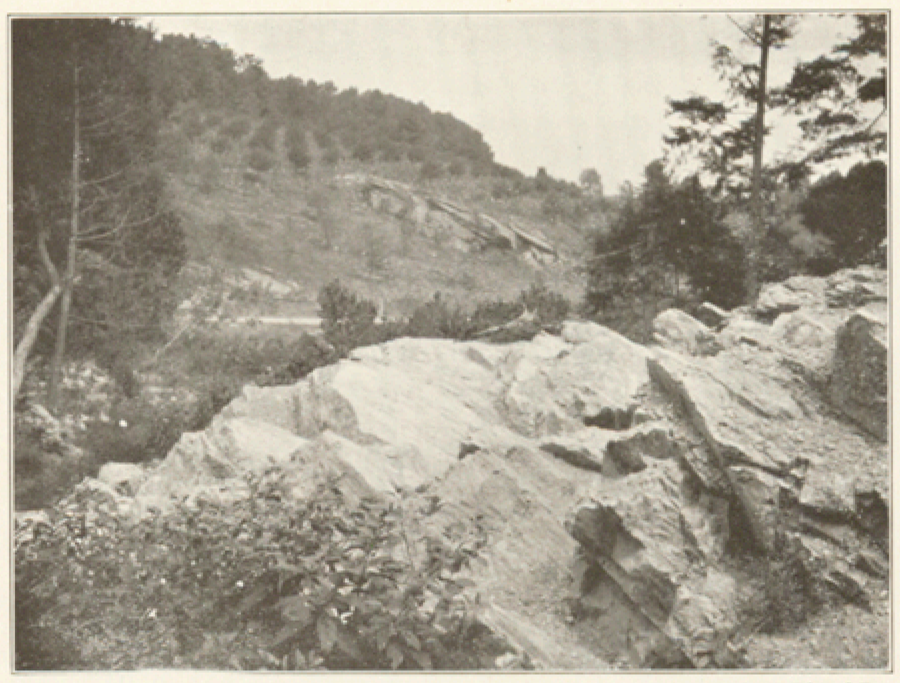


PLATE 1.—SCHISTOSE APORHYOLITE EXPOSED IN SMALL QUARRY WEST OF BRIDGEPORT
Schistosity dips southeast

PLATE 2.—MASSIVE BEDS OF WEVERTON SANDSTONE ON BARE ROCK, NORTH OF CHARMIAN

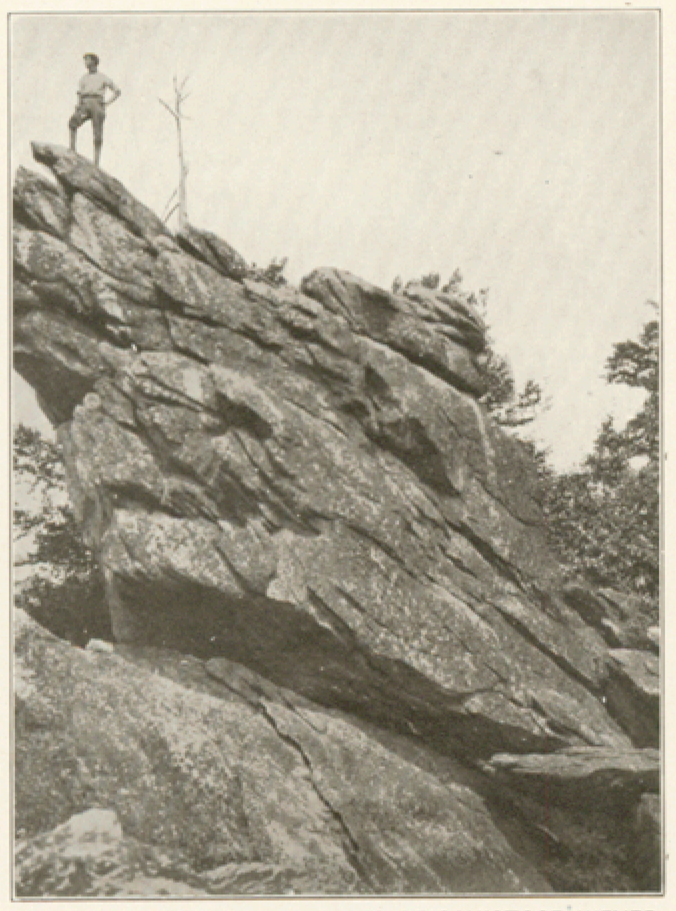


PLATE 3.—TYPICAL ROCK LEDGES OF SCHISTOSE WEVERTON SANDSTONE ON TOP OF SOUTH MOUNTAIN AT HAMMOND ROCKS, NORTH OF GETTYSBURG QUADRANGLE

PLATE 4.—SLATE AT BASE OF LOUDOUN FORMATION IN OLD QUARRY ON EAST SLOPE OF PINEY MOUNTAIN, WEST OF WENKSVILLE

PLATE 5.—POROUS SANDSTONE RESIDUAL FROM SANDY CONESTOGA LIMESTONE AT McSHERRYSTOWN
Crumbles to rounded sand grains and is quarried for building sand

PLATE 6.—TYPICAL TALUS OF ANTIETAM SANDSTONE AT TOP OF FRONT KNOBS OF SOUTH MOUNTAIN, OVERLOOKING CUMBERLAND VALLEY, AT STONY KNOB, JUST WEST OF FAIRFIELD QUADRANGLE.

PLATE 7.—DEVILS DEN, ROCKY LEDGES OF DIABASE OF THE GETTYSBURG SILL, NORTHWEST OF ROUND TOP
Here part of the battle of Gettysburg was fought hand to hand

PLATE 8.—RESIDUAL BOULDERS FROM A DIABASE DIKE NEAR BOWLDER
These boulders are similar to the ironstones that were made into fences and used as barricades by both armies in the battle of Gettysburg

PLATE 9.—SPHERICAL EXFOLIATION OF WEATHERED DIABASE, 1 MILE SOUTH OF BAKER SCHOOL
The ball-like mass rests on sand and soil derived from the complete disintegration of the diabase

PLATE 10.—VESICULAR DIABASE
The thin porous layer is at the upper contact of a 30-foot diabase sill in Triassic shale, just east of Heidlersburg

PLATE 11.—LAVA FLOW NEAR BENDERSVILLE
Fragments of vesicular lava inclosed in red sandy matrix overlying red sandstone

PLATE 12.—ROUND TOP, A CONICAL KNOB OF DIABASE
Gettysburg Battlefield in foreground

PLATE 13.—EAST FACE OF BIG HILL NORTH OF ARENDTSVILLE
The hill, composed of resistant pre-Cambrian aporhyolite, rises abruptly above the Gettysburg plain in foreground

PLATE 14.—THE NARROWS, A SHARP ROCKY GAP CUT BY CONEWAGO CREEK THROUGH THE BIG HILL-BEAR MOUNTAIN APORHYOLITE RIDGE
The even crest of the mountains represents an old peneplain surface

PLATE 15.—FOLDED THIN-BEDDED WEVERTON QUARTZITE AT EAST PORTAL OF WESTERN MARYLAND RAILWAY TUNNEL IN TUNNEL HILL

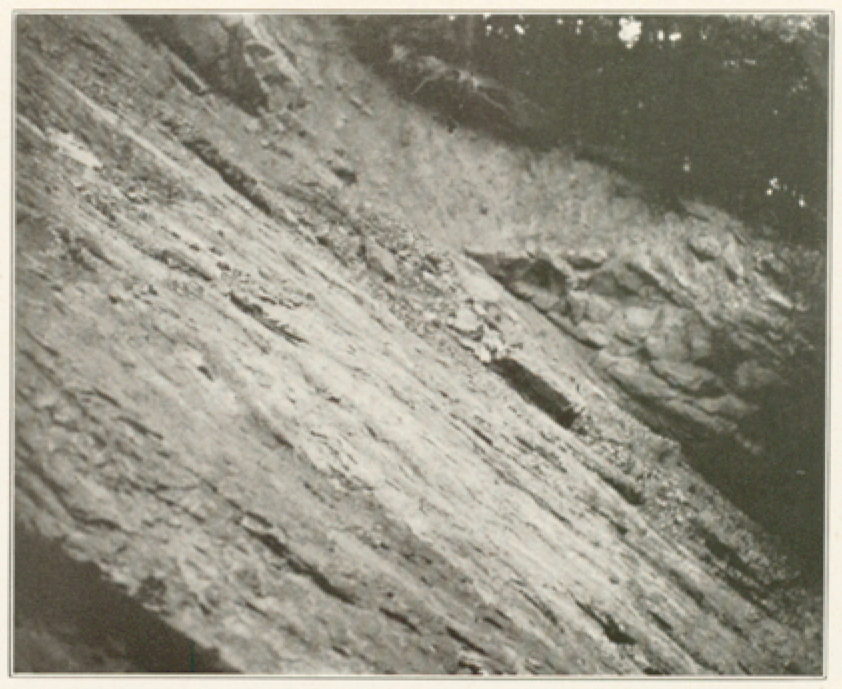


PLATE 16.—FAULT CONTACT BETWEEN WEVERTON SANDSTONE AND PRE-CAMBRIAN APORHYOLITE IN OLD TAPEWORM RAILROAD CUT 1 MILE WEST OF IRON SPRINGS
The sandstone has been thrust over the aporhyolite, and the fault plane dips 40° SE.

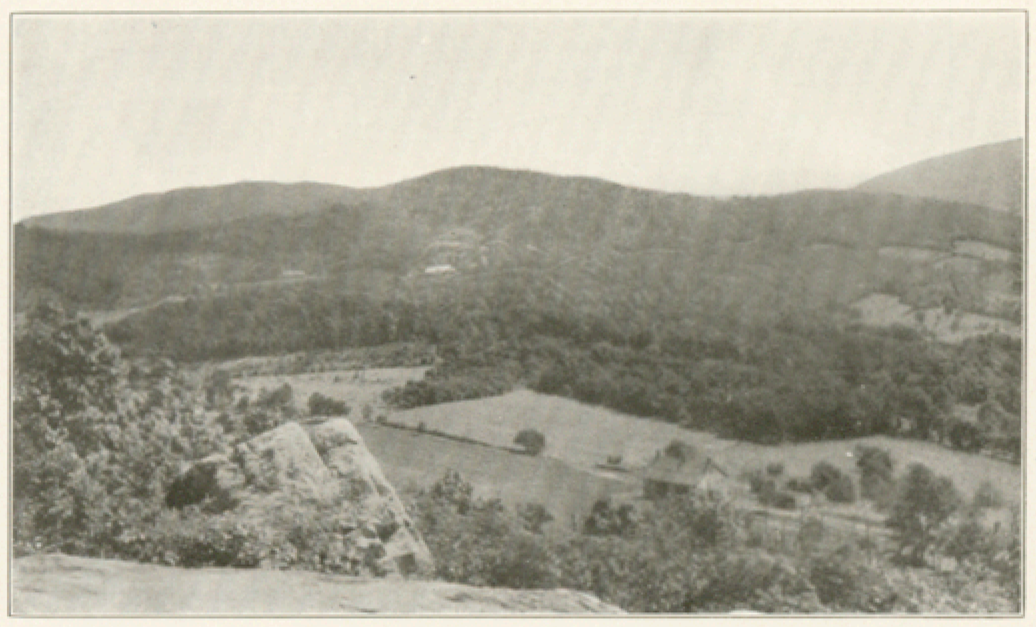


PLATE 17.—TUNNEL HILL AND VALLEY OF MINEY BRANCH VIEWED FROM BARE ROCK, NORTH OF CHARMIAN
The mountain is capped by Cambrian quartzite overlying greenstone, which is quarried at the foot of the mountain

PLATE 18.—STREAM CULVERT BUILT OF WEVERTON SANDSTONE ON ABANDONED TAPEWORM RAILROAD ON FLANK OF JACKS MOUNTAIN
Overgrown with large white pines

PLATE 19.—VIEW DOWN MARSH CREEK VALLEY FROM THE DIVIDE AT NEWMAN SCHOOL
The valley lies along a shear zone in greenstone

PLATE 20.—OLD QUAKER MEETINGHOUSE NEAR BERMUDIAN CHURCH
Built in eighteenth century of Triassic red sandstone

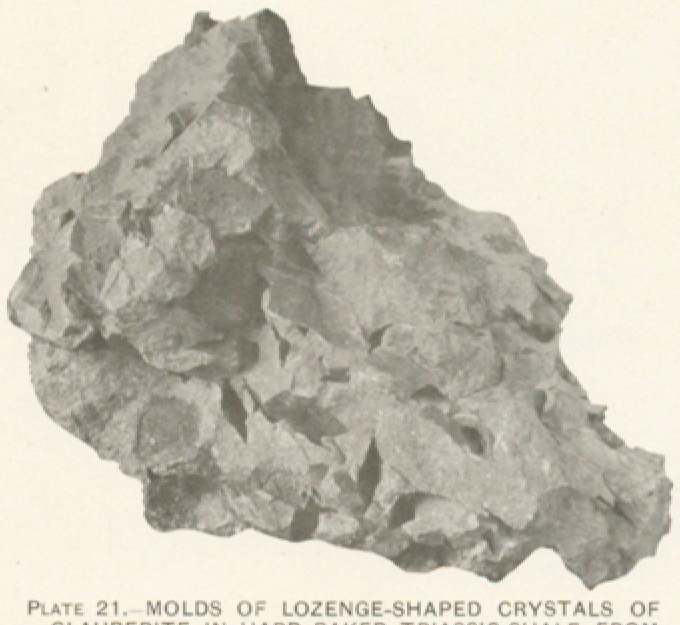


PLATE 21.—MOLDS OF LOZENGE-SHAPED CRYSTALS OF GLAUBERITE IN HARD BAKED TRIASSIC SHALE, FROM A POINT NEAR GOLDENVILLE
The mud in which these crystals grew was deposited in ponded water under arid climatic conditions

PLATE 22.—MOLD OF A LOZENGE-SHAPED CRYSTAL OF GLAUBERITE FROM A POINT NEAR GOLDENVILLE

PLATE 23.—EPIDOTIC CONCRETIONS IN ALTERED TRIASSIC SHALE METAMORPHOSED BY DIABASE INTRUSION 5 MILES SOUTH OF GETTYSBURG

PLATE 24.—DEVILS RACECOURSE IN SOUTH MOUNTAIN, WEST OF GLADHILL
Composed of Cambrian quartzite boulders stripped of soil, on an old peneplain surface, now forming a valley floor

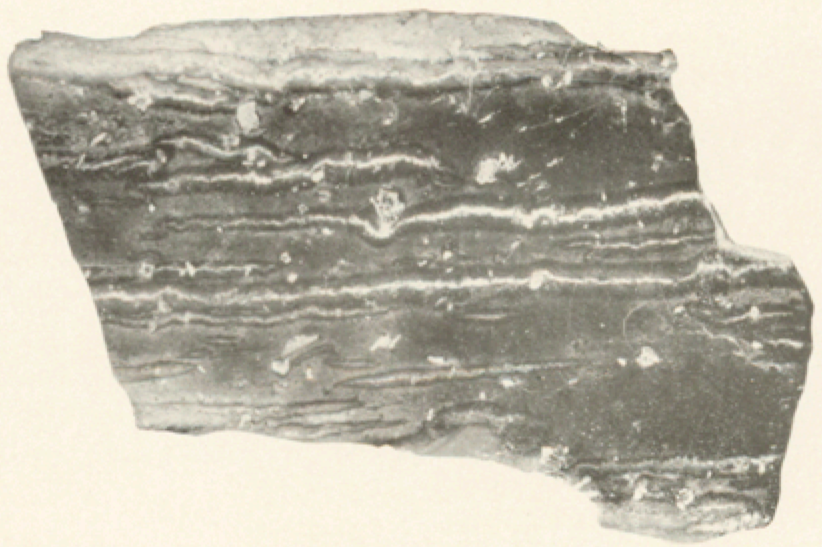


PLATE 25.—APORHYOLITE BANDED BY CHAIN SPHERULITES, FROM RACCOON CREEK, NORTHWEST OF SOUTH MOUNTAIN SANATORIUM

Bright-red rock with darker-red streaks bordering white spherulitic bands. Spherulitic fabric replaced by granular fabric. Polished specimen

PLATE 26.—BANDS OF COARSE SPHERULITES IN DARK DEVITRIFIED APORHYOLITE GLASS, FROM RACCOON CREEK

PLATE 27.—APORHYOLITE BANDED BY CHAIN SPHERULITES, FROM CORLS RIDGE, NORTH OF SOUTH MOUNTAIN SANATORIUM

Spherulitic fabric replaced by granular fabric

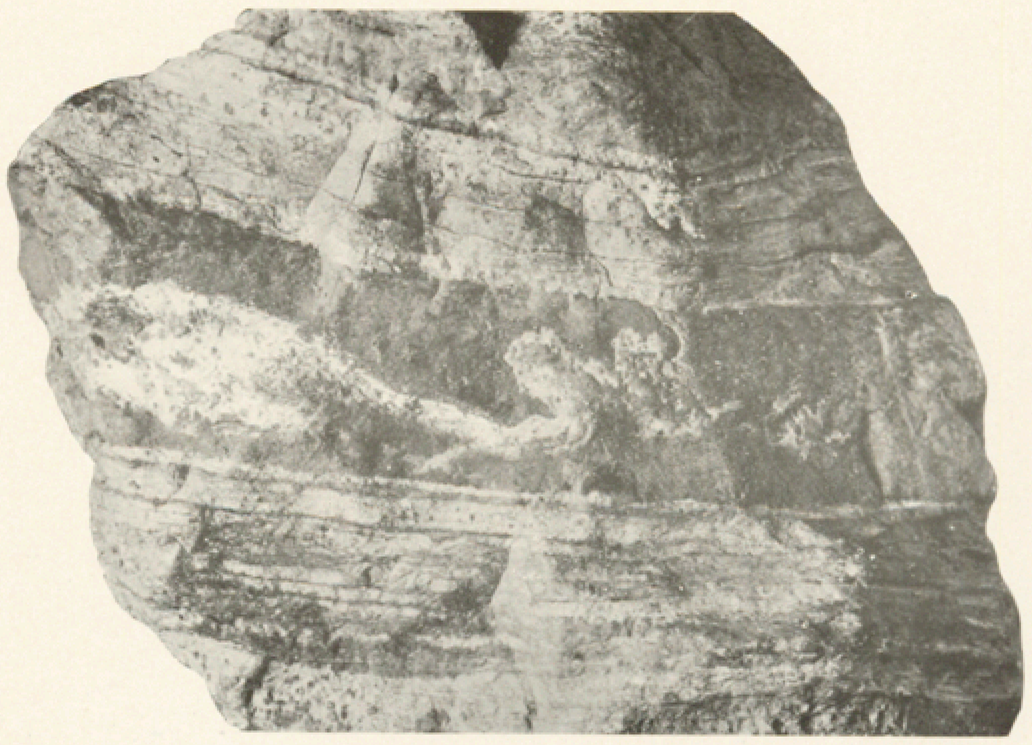


PLATE 28.—FLOW BANDING IN APORHYOLITE FROM RACCOON CREEK

Exhibits drag folds in devitrified layer

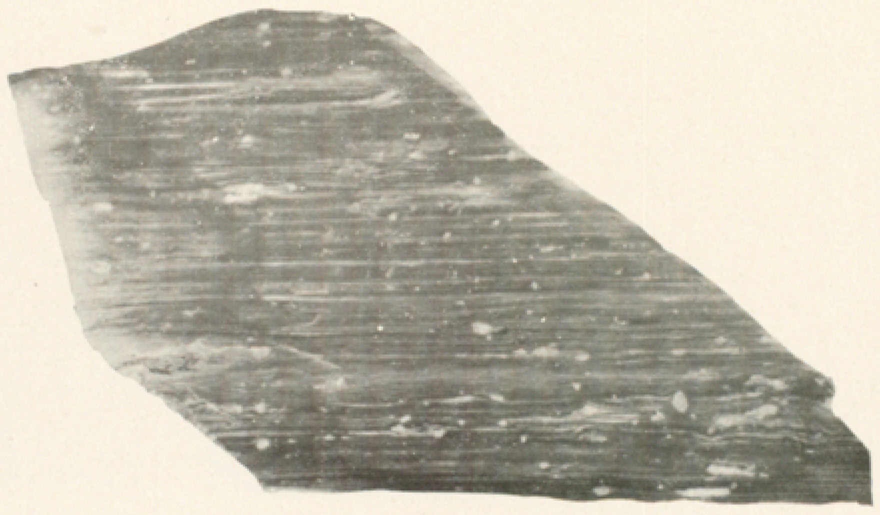


PLATE 29.—FINELY LAMINATED GRAY APORHYOLITE, FROM SOUTH SLOPE OF BIG HILL, 1 MILE NORTHWEST OF CASHTOWN

The fine, even flow banding bends around the white to pink feldspar phenocrysts. Polished specimen

PLATE 30.—LARGE ROUND SPHERULITES IN APORHYOLITE, FROM A POINT NEAR MOUTH OF COPPER RUN

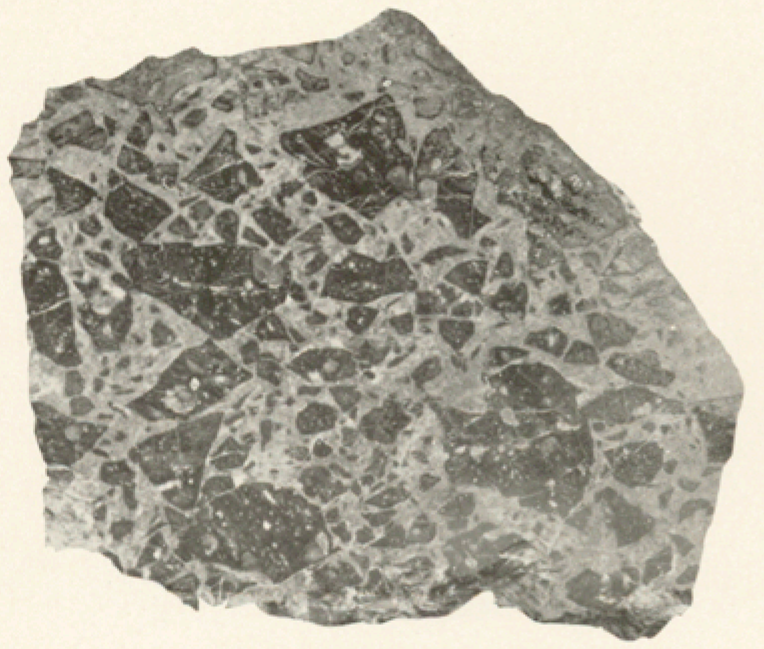


PLATE 31.—RHYOLITE FLOW BRECCIA, FROM A POINT 2 MILES SOUTHEAST OF SOUTH MOUNTAIN SANATORIUM

Angular fragments of red rhyolite cemented into a breccia by quartz. Polished specimen

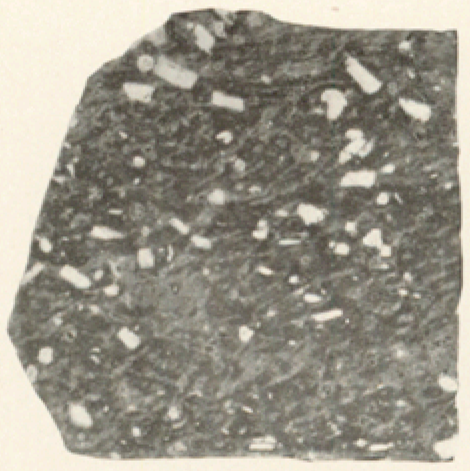


PLATE 32.—DARK-GRAY PORPHYRY SPOTTED WITH RECTANGULAR WHITE FELDSPAR PHENOCRYSTS, FROM HEAD OF MARSH CREEK HOLLOW

Polished specimen

PLATE 33.—MOTTLED GREEN AND PINK AMYGDALOIDAL APORHYOLITE, FROM BINGHAM COPPER MINE, NORTH OF PINE MOUNTAIN

A handsome ornamental rock with large amygdules of pink quartz the centers of which are stained green by copper carbonate. Polished specimen

PLATE 34.—DENSE FELSITIC APORHYOLITE, FROM FOOT OF ROCKY MOUNTAIN, 2 MILES SOUTH OF CALEDONIA FURNACE

Shows dark-purple and gray flow banding

PLATE 35.—RHYOLITE BRECCIA, FROM A LOCALITY 1 MILE NORTH OF BRADY SCHOOL, BUCHANAN VALLEY

Rhyolite tuff fragments inclosed in a finer red tuff matrix

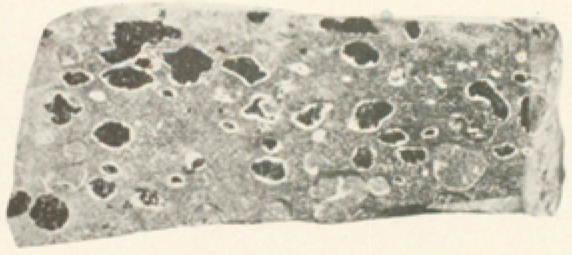


PLATE 36.—AMYGDALOIDAL METABASALT, FROM A POINT NEAR SOUTH MOUNTAIN SANATORIUM

Vesicles filled with dark-green epidote with a lining of milk-white quartz. Polished specimen

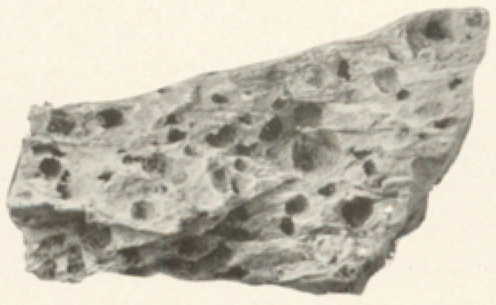


PLATE 37.—WEATHERED AMYGDALOIDAL GREENSTONE, FROM PIGEON HILLS, 1¼ MILES NORTHEAST OF BITTINGER

The brown-weathered rock is pitted with round holes from which the filling, probably calcite, has been dissolved

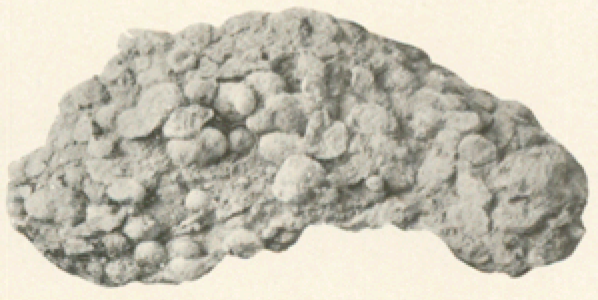


PLATE 38.—WEATHERED AMYGDALOIDAL METABASALT, FROM FOOT OF WILDCAT ROCKS

The round quartz amygdules stand in relief on the weathered surface

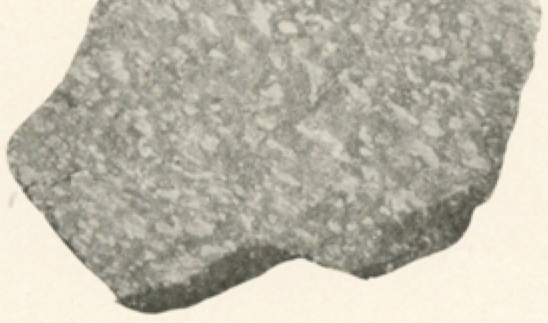


PLATE 39.—SPOTTED VOLCANIC SLATE, FROM A POINT JUST SOUTH OF CHARMIAN

Fragments of basaltic tuff flattened to shiny flakes

When it is desirable to recognize and map one or more specially developed parts of a formation the parts are called *members* or by some other appropriate term, such as *lentils*.

AGE OF THE FORMATIONS.

Geologic time.—The largest divisions of geologic time are called *eras*, the next smaller are called *periods*, and the still smaller divisions are called *epochs*. Subdivisions of the Pleistocene epoch are called *stages*. The age of a rock is expressed by the name of the time division in which it was formed.

The sedimentary formations deposited during a geologic period are called a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

As sedimentary deposits accumulate successively the younger rest on the older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or their relations to adjacent beds have been changed by faulting, so that it may be difficult to determine their relative ages from their present positions at the surface.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them or were buried in surficial deposits on the land. Such rocks are said to be fossiliferous. A study of these fossils has shown that the forms of life at each period of the earth's history were to a great extent different from the forms at other periods. Only the simpler kinds of marine plants and animals lived when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived forms that did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. If two sedimentary formations are geographically so far apart that it is impossible to determine their relative positions the characteristic fossils found in them may determine which was deposited first. Fossils are also of value in determining the age of formations in the regions of intense disturbance mentioned above. The fossils found in the strata of different areas, provinces, and continents afford the most effective means of combining local histories into a general earth history.

It is in many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or lies upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

Symbols, colors, and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern and is labeled by a special letter symbol.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations that are known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. The colors in which the patterns of parallel lines are printed indicate age, a particular color being assigned to each system.

Each symbol consists of two or more letters. The symbol for a formation whose age is known includes the system symbol, which is a capital letter or monogram; the symbols for other formations are composed of small letters.

The names of the geologic time divisions, arranged in order from youngest to oldest, and the color and symbol assigned to each system are given in the subjoined table.

Geologic time divisions and symbols and colors assigned to the rock systems.

Era.	Period or system.	Epoch or series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent Pleistocene	Q	Brownish yellow.
	Tertiary	Pliocene Miocene Oligocene Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		Tr	Peacock-blue.
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Є	Brick-red.
Proterozoic	Algonkian		A	Brownish red.
	Archean		AR	Gray-brown.

DEVELOPMENT AND SIGNIFICANCE OF SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. Most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains that border many streams were built up by the streams; waves cut sea cliffs, and waves and currents build up sand spits and bars. Surface forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 1 is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is built and afterward partly eroded away. The shaping of a plain along a shore is usually a double process, hills being worn away (*degraded*) and valleys filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wears them down, producing material that is carried by streams toward the sea. As this wearing down depends on the flow of water to the sea it can not be carried below sea level, which is therefore called the *base-level* of erosion. Lakes or large rivers may determine base-levels for certain regions. A large tract that is long undisturbed by uplift or subsidence is worn down nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted it becomes a record of its former close relation to base-level.

THE GEOLOGIC MAPS AND SHEETS IN THE FOLIO.

Areal-geology map.—The map showing the surface areas occupied by the several formations is called an *areal-geology map*. On the margin is an explanation, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the explanation, where he will find the name and description of the formation. If he desires to find any particular formation he should examine the explanation and find its name, color, and pattern and then trace out the areas on the map corresponding in color and pattern. The explanation shows also parts of the geologic history. The names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and metamorphic rocks of unknown origin—and those within each group are placed in the order of age, the youngest at the top.

Economic-geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic-geology map*. Most of the formations indicated on the areal-geology map are shown on the economic-geology map by patterns in fainter colors, but the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral product mined or quarried. If there are important mining industries or artesian basins in the area the folio includes special maps showing these additional economic features.

Structure-section sheet.—The relations of different beds to one another may be seen in cliffs, canyons, shafts, and other natural and artificial cuttings. Any cutting that exhibits these relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of the beds or masses of rock in the earth is called *structure*, and a section showing this arrangement is called a *structure section*.

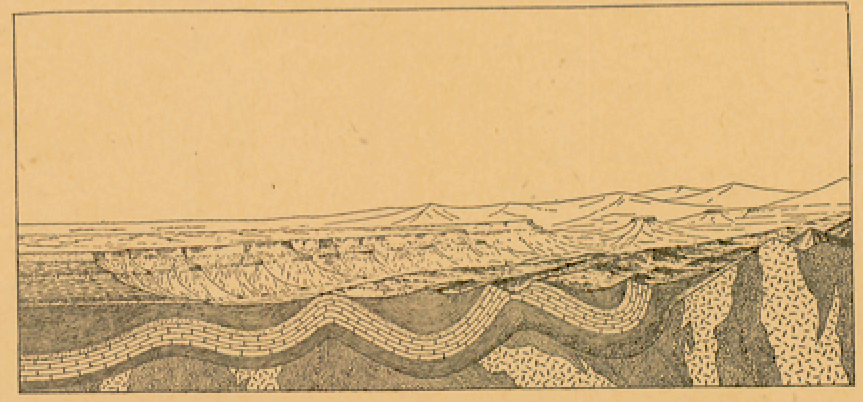


FIGURE 2.—Sketch showing a vertical section below the surface at the front and a view beyond.

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, after tracing out the relations of the beds on the surface he can infer their relative positions beneath the surface and can draw sections representing the probable structure to a considerable depth. Such a section is illustrated in figure 2.

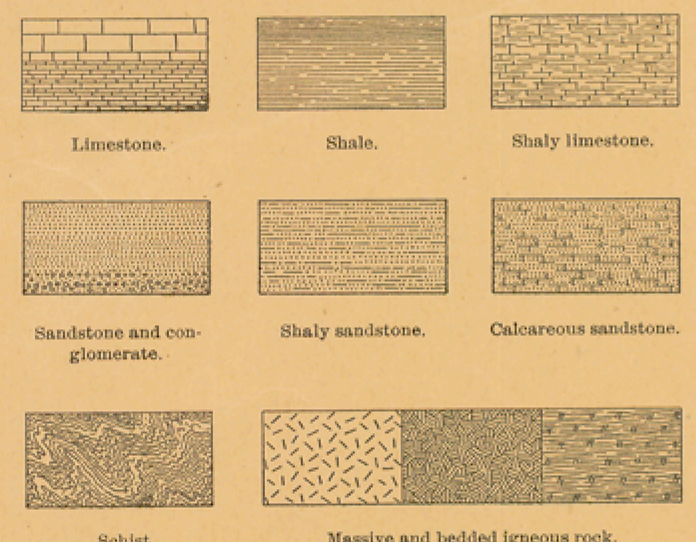


FIGURE 3.—Symbols used in sections to represent different kinds of rock.

The figure represents a landscape that is cut off sharply in the foreground on a vertical plane so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, made up of sandstone, which forms the cliffs, and shale, which forms the slopes. The broad belt of lower land is traversed by several ridges, which, as shown in the section, correspond to the outcrops of a folded bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the beds appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed, and by means of these observations their positions underground are inferred. The direction of the intersection of the surface of a dipping bed with a horizontal plane is called its *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called its *dip*.

In many regions the beds are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the materials that formed the sandstone, shale, and limestone were deposited beneath the sea in nearly flat layers the fact that the beds are now bent and folded shows that forces have from time to time caused the earth's crust to wrinkle along certain zones. In places the beds are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in figure 4.

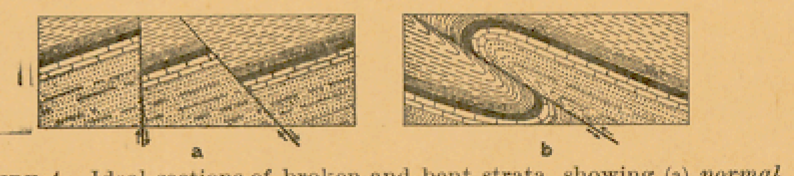


FIGURE 4.—Ideal sections of broken and bent strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted, and the form or arrangement of their masses underground can not be inferred. Hence that part of the section shows only what is probable, not what is known by observation.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of beds of sandstone and shale, which lie in a horizontal position. These beds were laid down under water but are now high above the sea, forming a plateau, and their change of altitude shows that this part of the earth's surface has been uplifted. The beds of this set are *conformable*—that is, they are parallel and show no break in sedimentation.

The next lower set of formations consists of beds that are folded into arches and troughs. The beds were once continuous, but the crests of the arches have been removed by erosion. These beds, like those of the upper set, are conformable.

The horizontal beds of the plateau rest upon the upturned, eroded edges of the beds of the middle set, as shown at the left of the section. The beds of the upper set are evidently younger than those of the middle set, which must have been folded and eroded between the time of their deposition and that of the deposition of the upper beds. The upper beds are *unconformable* to the middle beds, and the surface of contact is an *unconformity*.

The lowest set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and intruded by masses of molten rock. The overlying beds of the middle set have not been traversed by these intrusive rocks nor have they been affected by the pressure of the intrusion. It is evident that considerable time elapsed between the formation of the schists and the beginning of the deposition of the beds of the middle set, and during this time the schists were metamorphosed, disturbed by the intrusion of igneous masses, and deeply eroded. The contact between the middle and lowest sets is another unconformity; it marks a period of erosion between two periods of deposition.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps in much the same way that the section in the figure is related to the landscape. The profile of the surface in each structure section corresponds to the actual slopes of the ground along the section line, and the depth to any mineral-producing or water-bearing bed shown may be measured by using the scale given on the map.

Columnar section.—Many folios include a *columnar section*, which contains brief descriptions of the sedimentary formations in the quadrangle. It shows the character of the rocks as well as the thickness of the formations and the order of their accumulation, the oldest at the bottom, the youngest at the top. It also indicates intervals of time that correspond to events of uplift and degradation and constitute interruptions of deposition.

THE TEXT OF THE FOLIO.

The text of the folio states briefly the relation of the area mapped to the general region in which it is situated; points out the salient natural features of the geography of the area and indicates their significance and their history; considers the cities, towns, roads, railroads, and other human features; describes the geology and the geologic history; and shows the character and the location of the valuable mineral deposits.

GEORGE OTIS SMITH,
Director.

January, 1924.

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