CARROLL AND FREDERICK COUNTIES

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BOARD OF NATURAL RESOURCES
DEPARTMENT OF GEOLOGY, MINES AND WATER RESOURCES
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THE PHYSICAL FEATURES OF CARROLL COUNTY AND FREDERICK COUNTY

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PREFACE

This report on Carroll and Frederick Counties is the twelfth in a series of county reports that was started in 1900 and planned to ultimately include all of the counties of the State. The previous reports covered a single county. Since the geographic boundary between Carroll and Frederick Counties is not a geological boundary, and since the geology of the two counties can more advantageously be presented as a geologic unit, the two counties are included in a single volume.

The county reports supplement and describe the four series of county maps that were initiated by the Maryland Geological Survey and which are published on the scale of one inch equals one mile. The basic series on which the other three series are over-printed are the county topographic maps with a contour interval of 20 feet. Many of the original county topographic maps have been revised and reprinted from time to time. The latest editions of the Carroll County and Frederick County topographic maps are 1937 and 1942, respectively. Between 1902 and 1929, the Maryland Geological Survey published county soil maps for all of the counties of the State. The Carroll County and Frederick County soil maps were published in 1922 and 1925, respectively. Between 1905 and 1914, the Maryland Geological Survey published forestry maps of nine counties. The Frederick County forestry map was published in 1913, but no forestry map was published of Carroll County. Geologic maps of Carroll County and Frederick County were published in 1928 and 1938 respectively. The reader of this report will be greatly aided if he provides himself with these county maps, which are now distributed by the Department of Geology, Mines and Water Resources.

The county reports are the most comprehensive and complete descriptions of the natural resources of the counties of Maryland that are available. They describe the geography, physiography, geology, mineral resources, surface water resources, ground water resources, soils, forests, climate, and magnetic declination of the counties. The reports are encyclopedic in scope, each section being written by an authority in the particular subject matter, and natural resources are included beyond the field of the Department of Geology, Mines and Water Resources. The completion of each county report is an outstanding testimonial to the unselfish devotion of those engaged in the investigation of natural resources to maximum public service and of the spirit of cooperation in which they work. The authors of the sections in the Carroll and Frederick County report include personnel in both Federal and State conservation agencies who contributed their sections outside of their regular duties. The Director expresses his deep appreciation to those who contributed to this volume both for the spontaneous willingness with which they responded and for the excellence of their contributions.

The reports are designed primarily to serve as geologic reports to accompany the geologic maps, so that the section on geology in this report as in previous reports is the longest section. The authors of this section are properly the authors of the Carroll County and Frederick County geologic maps, Dr. Anna Jonas Stose and Dr. George W. Stose. The area covered by Carroll and Frederick Counties is part of a much larger region, extending to the north and to the south of Maryland, characterized by very difficult and complex geology. In the course of the years since the publication of the Carroll County geologic map, the authors not only mapped Frederick County but extended their geologic investigations beyond the boundaries of both counties. Their more extensive investigations led to revision of some of their correlations and structural interpretations in Carroll County on the Frederick County geologic map published 10 years later, and have led to some further revision in this report of their interpretations of the geology of both counties in the seven years that elapsed since the publication of the Frederick County map. In order to complete the geologic unit of the Blue Ridge, the Frederick County geologic map overlaps onto the eastern edge of Washington County. In 1941 the Maryland Geological Survey published the geological map of Washington County by Dr. Ernst Cloos, and that map does not conform completely with the Frederick County map where the two overlap, the geologists differing somewhat in correlation of formations and in structural interpretations. These differences of opinion and interpretation are discussed by the authors of the geologic section of this report. That the "authorities" are not in complete agreement on the interpretation of the geology, however, does not impair the usefulness of the maps as areal geology maps. The briefer introductory section on the geography and physiography of the two counties was also written by the Stoses.

The section on the mineral resources was written by the Director of the Department of Geology, Mines and Water Resources.

The section on the surface water resources was prepared by the late A. H. Horton, district engineer of the United States Geological Survey. The section on ground water resources is by Mr. Robert R. Bennett, geologist of the United States Geological Survey, in charge of the ground water investigations in Maryland conducted cooperatively by the United States Geological Survey and the Maryland Department of Geology, Mines and Water Resources.

The section on the soils is under the joint authorship of Mr. F. G. Loughry and Mr. D. C. Taylor, of the Regional Soil Conservation Surveys Division, Soil Conservation Service, United States Department of Agriculture.

The section on the forests is by Mr. Joseph F. Kaylor, State Forester and Director of the Maryland Department of State Forests and Parks.

The section on climate was written by Mr. Joseph Bily, Jr., official in charge, Weather Bureau, Baltimore, Maryland, United States Department of Commerce.

The section on magnetic declination was prepared under the supervision of Mr. O. W. Swainson, Chief, Division of Geomagnetism and Seismology, United States Coast and Geodetic Survey.

JOSEPH T. SINGEWALD, JR., *Director.*

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BY

ANNA J. AND GEORGE W. STOSE

Location and General Description

Frederick County lies near the center of Maryland and extends across the State from the Virginia State line on the south to the Pennsylvania State line on the north. Its western boundary follows the crest of the nearly north-trending South Mountain, which is the main ridge of the Appalachian Mountains in Maryland and Pennsylvania. The north boundary is the east-trending Mason and Dixon line which separates Maryland from Pennsylvania. The south boundary follows the south shore of Potomac River to a point where the river bends sharply southward. From this point the south boundary, which separates Frederick County from Montgomery County, is a straight line running northeastward to Ridgeville. The east boundary of the county, which separates it from Carroll County, is an irregular north-trending line along Parrs Ridge. Farther north the county line follows Little Pipe Creek, Double Pipe Creek, and Monocacy River to the Pennsylvania State line. See Fig. 1.

Frederick, the county seat and largest city in the county, is in the Frederick Valley, near the center of the county. Its population in 1940 was 15,802. The other incorporated towns in the county are Brunswick (population 3856), Emmitsburg (1412), Thurmont (1307), Middletown (839), Walkersville (731), Woodsboro (416), Point of Rocks (370), New Market (360), and Myersville (310). Unincorporated towns are Urbana, Jefferson, Lewisburg, Libertytown, Johnsville, and Mt. Pleasant. Ridgeville and Mt. Airy straddle the Frederick-Carroll County line on Parrs Ridge, and Blue Ridge Summit is at the north edge of the county in Pennsylvania.

Carroll County lies east of the central and northern part of Frederick County. Its north boundary is the Mason and Dixon line. Its south boundary follows the South Branch of Patapsco River, which separates Carroll County from Howard County, and extends to its junction with the North Branch. The east boundary of Carroll County, which separates it from Baltimore County, follows the North Branch of Patapsco River to a fork in the stream, and north of that point, the boundary is a straight line trending north-northeast to the Maryland-Pennsylvania State line.

The county seat, Westminster, is the largest city in Carroll County and has a population of 4,692. Other incorporated towns in the county are Taneytown (population 1,208), Union Bridge (831), Sykesville (806), Mt. Airy (791), Hampstead (664), and New Windsor (529).

The Frederick Valley is the most settled part of Frederick and Carroll Counties. This lowland is largely cultivated, and its deep fertile residual limestone soil makes it the best farmland in the counties. The flat hilltops and gentle slopes of the Triassic upland, north of Frederick Valley, have a light sandy soil which is also extensively cultivated, and this upland is well settled. In the eastern part of Frederick County and the adjoining part of Carroll County, a narrow belt within the Piedmont upland is underlain by volcanic rocks and marble and is also a fertile farming country. This belt passes northeastward through Westminster to the north boundary of Carroll County. The remaining parts of the Piedmont upland are more rugged and hilly and

FIG. 1. Index Map of Maryland, showing location of Frederick and Carroll Counties.

include the broad tops of Parrs Ridge and Dug Hill Ridge. The upland surface is in part sparsely settled and cultivated; the deep steep-sided valleys and ravines are largely wooded. Catoctin and South Mountains have poor thin soil and are wooded, with patches of cleared fields and pastureland on the flatter summits. The mountains are crossed by few roads and have few habitations. Parts of the Middletown Valley, between the high ridges, have gentle rolling hills which are occupied by farms, but the northern part of this valley is much more rugged, is cut by deep steep-sided valleys, and is largely wooded and sparsely settled.

RAILROADS AND HIGHWAYS

Frederick and Carroll Counties are crossed by the main line of the Baltimore and Ohio Railroad to Baltimore which follows the north side of Potomac River to Point of Rocks. One mile east of that town it leaves the Potomac floodplain, crosses the Frederick Valley, and ascends northeastward to Ridgeville on Parrs Ridge, where it tunnels the ridge into Carroll County. Eastward it descends the valley of the South Branch of Patapsco River and passes out of Carroll County into Baltimore County at the junction of the South and North Branches of Patapsco River. A short shuttle branch of the railroad extends from Frederick Junction to its terminus at Frederick. The Metropolitan Branch of the Baltimore and Ohio Railroad, the main passenger route to Washington, follows the north side of Potomac River from Point of Rocks eastward to the Montgomery County boundary.

The main line of the Western Maryland Railroad enters Frederick County from Pennsylvania at Blue Ridge Summit on South Mountain. It descends the east slope of the mountain and passes through Catoctin Mountain in the gorge of Owens Creek. From Thurmont, at the east foot of Catoctin Mountain, it runs eastward across the Triassic upland and the Piedmont upland, passing through Union Bridge, New Windsor, and Westminster. At Westminster it crosses Parrs Ridge at a low divide and descends the ridge eastward along the West Branch of the North Branch of Patapsco River. It passes into Baltimore County at the mouth of the West Branch.

The Frederick Branch of the Northern Central Railroad enters Carroll County from Pennsylvania and passes through Taneytown on the Triassic upland and crosses the Western Maryland Railroad at Keymar. It enters the Frederick Valley north of Woodsboro and has its terminus at Frederick. The Frederick Railroad runs north from Frederick, through Lewistown and Catoctin, to Thurmont, where it joins the Western Maryland Railroad. An electric trolley line connecting Hagerstown and Frederick crosses South Mountain at Smoketown Gap and passes through Myerstown and Middletown. It crosses Catoctin Mountain at the low divide at Braddock Heights.

Frederick and Carroll Counties are crossed by several through highways and by many other hard surfaced roads. U. S. Highway 40, the old Pittsburgh-Baltimore turnpike, crosses the counties from east to west and passes through Ridgeville, Frederick, Braddock Heights, and Middletown. It crosses South Mountain at Turners Gap. U. S. Highway 240, from Washington, D. C., to Frederick, passes through Urbana, close to Sugarloaf Mountain. U. S. Highway 15, from Harrisburg, Pa., runs southward through Emmitsburg and Frederick, and crosses Potomac River at Point of Rocks. U. S. Highway 340 extends southwest from Frederick through Knoxville to Harpers Ferry, W. Va. U. S. Highway 140 (the Reisterstown road) passes northwestward through Westminster, and leaves Carroll County near Littlestown, Pa. Many other hard-surfaced state highways radiate outward from Frederick, Westminster, Libertytown, Taneytown, Union Bridge, and other towns in the counties.

RELIEF

Frederick and Carroll Counties lie within the Appalachian Mountains and in the western part of the Piedmont. The Appalachian Mountains cross the western part of Frederick County. The rest of Frederick County and all of Carroll County are in the Piedmont. See Fig. 2.

APPALACHIAN MOUNTAINS

The Appalachian Mountains in Maryland consist of a mountainous belt 8 to 11 miles wide which trends east of north across the State. It comprises Catoctin Mountain at the east and the Blue Ridge at the west, with South Mountain and rugged hills and mountainous country between. Figure 2 shows the relations of these mountains and other physiographic features in this part of Maryland to related features in Pennsylvania and Virginia.

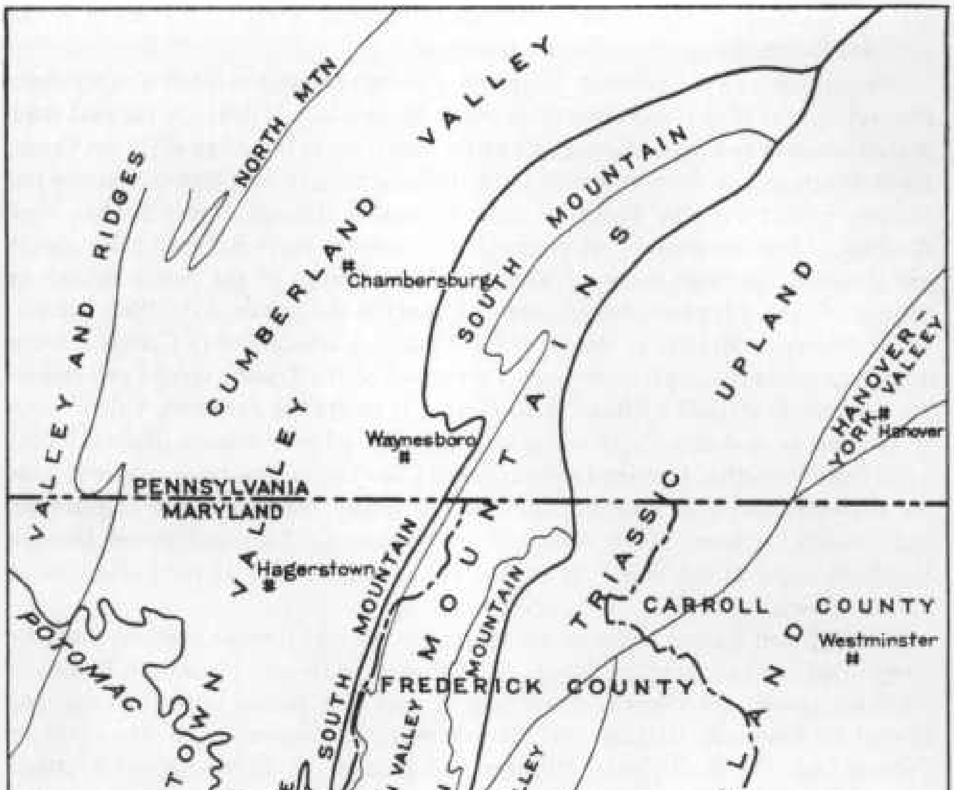

FIG. 2. Physiographic map of Frederick and Carroll Counties and adjacent areas in Pa. and Va. Shows the minor physiographic divisions of Piedmont Upland, Appalachian Mountains, and Appalachian Valley.

The Blue Ridge, a high continuous ridge which constitutes the main part of the Appalachian Mountains in Virginia north of Roanoke, extends only a short distance into Maryland, and ends west of Lambs Knoll on South Mountain. It lies in Washington County, where it is locally called Elk Ridge. South Mountain in Maryland near Potomac River is a narrow single ridge about 1200 feet in altitude. At Lambs Knoll it widens greatly and attains an altitude of 1772 feet. North of Lambs Knoll the ridge is again narrow and low as far as Smoketown Gap where it is crossed by U. S. Highway 40 and the Hagerstown-Frederick electric trolley line. North of Smoketown Gap the ridge widens to $1\frac{1}{2}$ miles and attains an altitude of over 1800 feet. Farther north, South Mountain becomes a double ridge. The eastern ridge, which is the drainage divide, is followed by the Frederick-Washington County line. The western, more rugged ridge (Pl. 1A), culminating in Quirauk Mountain, 2145 feet in altitude, lies in Washington County.

Catoctin Mountain between Potomac River and Braddock Heights (Pl. 1B) is a narrow ridge, not over 1125 feet in altitude, which rises abruptly above the Frederick Valley. North of Braddock Heights the main ridge of Catoctin Mountain is broad and flat topped, and has an altitude of about 1800 feet. East of the main ridge, long eastward-trending high spurs connect with high north-south trending ridges. Deep rocky stream gorges separate the high spurs. This mountainous belt, which has a maximum width of over 3 miles, contains some of the most beautiful scenery in the region. Wild rocky gorges abound along Little Tuscarora, Fishing, Little Hunting, and Owens Creeks, and prominent bare rock ledges on the tops of interstream ridges, such as Chimney, Wolf, Cat, Black, and White Rocks (Pls. 7–9), furnish view points of the mountains and lowlands to the east. Toward the north, near the north edge of Frederick County, Catoctin Mountain bends northeastward and ends in an abrupt escarpment on the east side of Carrick Knob.

The southern part of the mountainous tract between Catoctin and South Mountains is a rolling upland called the Middletown Valley. Its surface ranges from 500 to 600 feet in altitude, and is trenched to a depth of 200 to 300 feet by Catoctin Creek and its tributaries. The northern part of this inter-mountain upland is more rugged and its general surface rises northward to over 1800 feet altitude. Some of the stream valleys in this part of the upland trench the surface to a depth of over 800 feet.

PIEDMONT

The Piedmont, which lies east of the Appalachian Mountains, is in general an upland. The Piedmont is 55 miles wide in Maryland. It extends southwestward across the central part of the State from the Maryland-Pennsylvania State line to the Potomac River. It is divided into the Frederick Valley, the Triassic upland, and the Piedmont upland. · The Triassic upland and the Frederick Valley lie west of the Piedmont upland, which is underlain by crystalline schists.

The surface of the Piedmont upland has an average altitude of 700 to 800 feet, and is trenched by many deep narrow stream valleys. This upland culminates westward in a broad gentle ridge which crosses Carroll County in a northeasterly direction and has summits over 1000 feet in altitude in northern Carroll County. The southern part of this ridge is called Parrs Ridge (Pl. 2A), and the northern part Dug Hill

Ridge. Northwest of Dug Hill Ridge is another belt of high hills with a general altitude of 1000 to 1100 feet. Near the south edge of Frederick County a prominent ridge rises above the upland surface and culminates in a round peak, 1280 feet in altitude, called Sugarloaf Mountain (Pl. 2B). This isolated mountain is a prominent landmark.

The southwestern part of the Piedmont in Maryland is a lowland, extending from New Midway to the Potomac River, called the Frederick Valley. It has an altitude of about 300 feet and its maximum width is about 4 miles. North of Frederick Valley, low flat-topped hills with a general altitude of about 500 feet, underlain by Triassic sedimentary rocks, are the Triassic upland. The Triassic upland widens northward to 12 miles at the Maryland-Pennsylvania State line.

DRAINAGE

Most of Frederick and Carroll Counties is drained by the tributaries of Potomac River. Its main tributary, Monocacy River, flows southward across Frederick County and empties into the Potomac at the southernmost point of the county. Eastward-flowing tributaries of the Monocacy head in Catoctin Mountain and flow across the Triassic upland and Frederick Valley. One of these tributaries, Owens Creek, heads in the mountains west of Catoctin Mountain, and, west of Roddy, flows through a deep rocky gorge in that ridge. Toms Creek, which also heads in the mountains west of Catoctin Mountain, flows around the north end of that mountain and then southeastward across the Triassic upland to Monocacy River. Westward-flowing tributaries of the Monocacy head on the west slopes of Dug Hill Ridge and Parrs Ridge and flow across the Piedmont upland and the Triassic upland to Monocacy River. The largest of these tributaries are Pipe Creek and its main branch Little Pipe Creek, Bush Creek, and Bennett Creek.

Catoctin Creek, the only other large tributary of the Potomac in these counties, drains the Middletown Valley and most of the mountainous tract to the north between South and Catoctin Mountains. It follows a meandering southerly course and enters Potomac River west of Catoctin Mountain.

Most of the Piedmont upland east of Dug Hill Ridge and Parrs Ridge is drained by the North and South Branches of Patapsco River. These streams unite at the southeast corner of Carroll County and flow southeastward across Baltimore County into Chesapeake Bay. A small part of the northeast corner of Carroll County is drained by the headwaters of Gunpowder Falls which flows southeast into Gunpowder River and Chesapeake Bay.

PHYSIOGRAPHY

The topographic features and land forms in Frederick and Carroll Counties have been produced by the processes of erosion on a rising land. Since the Triassic period, this part of the continent has stood above sea level and has been subject to erosion. The rocks have been slowly worn away by rain, frost, wind, and streams, and the harder rocks, which have resisted erosion, compose the mountains and hills. During this time the land has been slowly rising higher and higher above sea level, but this elevation of the land has not been continuous. There were times during the uplift when the land was stable for long periods of time, and during one of these stable periods the whole land surface was reduced by erosion to a gently rolling plain with few residual hills.

The tops of the ridges of the Appalachian Mountains in southern Pennsylvania have an even crest line and some of the summits have broad flat areas. These are believed to be remnants of an old plateau surface now standing about 2000 feet in altitude. Flat areas on the top of Catoctin Mountain in the northern part of Frederick County, ranging from 1880 to 1800 feet altitude, and similar flat areas on the top of South Mountain at about 1800 feet altitude, are believed to represent this old plateau surface (Fig. 3). In fact, the three ridges of the Appalachian Mountains in a large part of their extent across Maryland, have an even, nearly level crest line at, or a little below, 1800 feet altitude, and are believed to be slightly lowered remnants of this plateau. Evidently this old plateau surface once extended over the whole region but is preserved only on mountains composed of resistant Lower Cambrian quartzite. The quartzite beds dip at various angles and have been truncated to form the plateau surface. This surface is believed, therefore, to have been formed by prolonged erosion while the land stood stationary at a much lower level for so long a time that even the hard Cambrian quartzites were worn down to a low rolling plain (Fig. 3). Quirauk Mountain on South Mountain, near the Pennsylvania State line, which is a rocky peak 2145 feet in altitude, was not completely reduced by erosion to the plateau level, and other peaks in southern Pennsylvania which attain 2400 feet altitude, are similar unreduced masses of quartzite. This plateau has been traced northward across Pennsylvania into New Jersey, where it was named the Schooley peneplain from Schooley Mountain, because the plateau surface is best preserved there. The period of stability of the land when this erosion surface was formed began before Cretaceous time, because Lower Cretaceous sediments were deposited on it in New Jersey, and continued into early Tertiary time.[1]

After the land surface was reduced by erosion to a peneplain, it was elevated and erosion was actively renewed. The streams cut deep channels and eroded the softer rocks, leaving the areas composed of hard rocks standing in relief. The main streams flowed eastward across this surface toward the sea, and, when they crossed belts of harder rock, they were able to cut only narrow gaps in them. Potomac River is such a major stream in Frederick County. Because its headwaters are far to the west, it had sufficient power to cut narrow gorges through the Blue Ridge, South Mountain, and Catoctin Mountain (Pl. 3). Delaware Water Gap in Pennsylvania, where the Delaware River cuts a narrow gorge through Kittatinny Mountain, was similarly formed.[2]

East of the Appalachian Mountains, there are high level tracts on Parrs Ridge, Dug Hill Ridge, and the hills near Wentz in Carroll County, which range from 1000 to 1100 feet in altitude. In the adjoining part of Pennsylvania similar flat-topped ridges at this level are more extensive and more numerous. They are remnants of

[1] Stose, G. W., Age of the Schooley peneplain. Am. Jour. Sci., 5th ser., vol. 238, pp. 461–476, 1940.

[2] Stose, G. W., Text on back of Delaware Water Gap, Pa., topographic map. U. S. Geol. Surv., 1942.

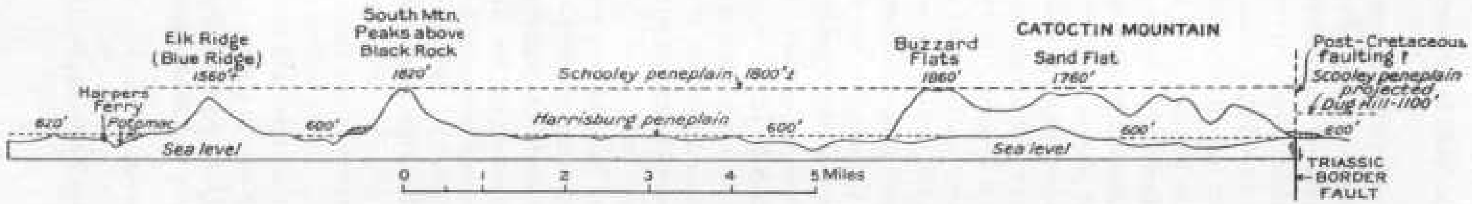

FIG. 3. Generalized profile across the structure of the Appalachian Mountains, showing the Schooley and Harrisburg peneplains and possible post-Cretaceous faulting which displaced the Schooley peneplain east of the mountains.

an old plateau surface and are believed to represent the Schooley peneplain, although they are much lower in altitude than the Schooley peneplain on Catoctin Mountain. In southern Pennsylvania, post-Cretaceous faulting in the Piedmont explains the difference in altitude between two parts of the Schooley peneplain.[3] It is probable, therefore, that recurrent movement on the Triassic border fault in post-Cretaceous time lowered the Schooley peneplain several hundred feet east of the fault in Carroll and Frederick Counties (Fig. 3).

In southern Pennsylvania, just north of Blue Ridge Summit, there is a level tract cut on less-resistant rocks at about 1400 feet altitude, between the higher ridges of South Mountain, and still farther north on South Mountain are other level tracts at about 1600 feet altitude underlain by similar less-resistant rocks. This surface is believed to represent a period of stability of the land after the formation of the Schooley peneplain, when erosion reduced the less-resistant rocks to a nearly flat surface. Benches and flat-topped areas on Catoctin Mountain and South Mountain in Frederick County at 1300–1400 feet altitude may represent this old land surface. South Mountain just north of Weverton at Potomac River has a level top 1200 feet in altitude, which Keith regarded as part of this old plateau surface and named it the Weverton peneplain. It may represent a temporary halt in the uplift of the land during which part of the land surface was reduced to a partial peneplain.

After the formation of the Schooley peneplain, and possibly the Weverton partial peneplain, renewed uplift of the land, accompanied by active erosion of the rocks, continued until late Tertiary time when the land again became stable, and a prolonged period of erosion at this level produced a partial peneplain on the softer rocks. This peneplain is represented by the dissected plateau, now standing at about 600 feet altitude, cut on the pre-Cambrian rocks in Pleasant Valley, between Elk Ridge and South Mountain, and on similar rocks in the Middletown Valley between South Mountain and Catoctin Mountain.

The Triassic upland, north of Frederick, was also reduced to this level, but most of this surface has been further lowered by later erosion of the soft Triassic sedimentary rocks. Chestnut Hill, at the south edge of the Triassic upland, is composed of Triassic conglomerate which is more resistant than the red shale and sandstone of the rest of the Triassic, and the plateau surface is still preserved on its top at 600 feet altitude. Coarse alluvial cones were poured out at this time on this old peneplain surface at the mouths of stream gorges in the east slope of Catoctin Mountain. The altitude of the gravel cap is about 600 feet, but later erosion has strewn the gravel to lower levels over the slopes below. Similar alluvial cones at the west foot of South Mountain in Washington County also represent this partial peneplain and have an altitude of about 600 feet (Fig. 3). In the southeastern part of Frederick County the flat upland around Urbana, at an altitude of 520 to 580 feet, represents this partial peneplain. Sugarloaf Mountain rises sharply above this plateau level as an unreduced monadnock on the peneplain surface.

This partial peneplain in the valley of Potomac River forms the upland surface of much of the land between higher mountain ridges into which the streams have

[3] Stose, G. W., Possible post-Cretaceous faulting in the Appalachians. Geol. Soc. Amer. Bull., vol. 38, pp. 493–504, 1927.

since cut their channels, and therefore it has been called the Valley Floor peneplain. The Valley Floor peneplain rises away from the river and gradually loses its flat character. In the valley of Susquehanna River in Pennsylvania, a similar Valley Floor peneplain is developed at approximately the same altitude. This surface has been named the Harrisburg peneplain from Harrisburg, Pa., and this name is also applied to the peneplain in Frederick County. These partial peneplains were probably cut during a halt in the uplift of the land in late Tertiary time.

After the formation of the Harrisburg peneplain, the land was again uplifted and active erosion was renewed. Several terraces above the flood plain of Potomac River, which are mostly covered with river gravel, mark stages of temporary halt in the uplift, probably during glacial stages of the Pleistocene epoch (Pl. 3). The higher terrace gravels contain scattered large boulders, up to 4 feet in size, which are grooved and striated by ice action. These higher terraces have not been definitely correlated with those of early Pleistocene age that have been mapped around Washington on the lower Potomac, but probably represent the Sunderland and Bryn Mawr gravel terraces of that area.

GEOLOGY OF CARROLL AND FREDERICK COUNTIES

BY

ANNA J. AND GEORGE W. STOSE

PREVIOUS WORK

George Huntington Williams began a survey of Carroll and Frederick Counties and neighboring areas for the Federal Geological Survey in 1888. He used as a base the old Frederick, Harpers Ferry, and other quadrangle maps on a scale of 2 miles to the inch. In 1891 Williams published a preliminary paper[1] on the Piedmont Plateau of Maryland. In 1892 he described[2] the volcanic rocks of South Mountain and proved that they are not of sedimentary origin as had been previously believed by other geologists. A preliminary geological map of Maryland, published in 1893, was edited by Williams. At the time of his death in 1894, he was working on the Frederick quadrangle and the area to the southeast in Maryland, including the vicinity of Washington. Keith was assigned by the Federal Survey to complete the area preliminarily mapped by Williams. In Keith's first publication[3] on the region he stated that the quartzites near Harpers Ferry were of Silurian age. Walcott,[4] in studying these quartzites, found that they contained Lower Cambrian fossils. Keith later described[5] the rocks of the Blue Ridge province in Maryland in his report on the Catoctin Belt, which includes a small scale geologic map and structure sections of the area.

The geology of the southwestern part of Frederick County was mapped and described by Keith in the Harpers Ferry folio.[6] Mathews[7] published the results of work in the Piedmont area, including the eastern part of Frederick County and Carroll County, in two papers. Mathews and Grasty[8] described the marbles of the

[1] Williams, G. H., The petrography and structure of the Piedmont Plateau of Maryland. Geol. Soc. Amer. Bull., vol. 2, pp. 301–317, 1891.

[2] Williams, G. H., Volcanic rocks of South Mountain in Pennsylvania and Maryland. Am. Jour. Sci., 2 ser., vol. 44, pp. 482–496, 1892; vol. 46, pp. 50–57, 1893. The distribution of volcanic rocks. Jour. Geol., vol. 2, pp. 1–31, 1894.

[3] Keith, Arthur, and Geiger, H. R., The structure of the Blue Ridge near Harpers Ferry. Geol. Soc. Amer. Bull., vol. 2, pp. 155–164, 1891.

[4] Walcott, C. D., Notes on the Cambrian rocks of Pennsylvania and Maryland from the Susquehanna to the Potomac. Am. Jour. Sci., 3rd ser., pp. 469–482, 1892.

[5] Keith, Arthur, Geology of the Catoctin Belt. U. S. Geol. Survey, Fourteenth Annual Rept., 1895.

[6] Keith, Arthur, Harpers Ferry folio. U. S. Geol. Survey Geol. Atlas, No. 10, 1894.

[7] Mathews, E. B., The Structure of the Piedmont Plateau as shown in Maryland. Amer. Jour. Sci., vol. 17, pp. 141–159, 1904.

———, Correlation of Maryland and Pennsylvania Piedmont formations. Geol. Soc. Amer. Bull., vol. 16, pp. 329–346, 1905.

[8] Mathews, E. B., and Grasty, J. S., Limestones of Maryland. Md. Geol. Survey, vol. 8, p. 351, 1910.

Piedmont area, and the limestones of the Frederick Valley they called the Shenandoah limestone. The operating quarries also were described. In this report Mathews gives a general discussion of the geology of the western Piedmont of Maryland.

In an earlier report by Keyes,[9] the Shenandoah limestone of the Frederick Valley was separated into Beekmantown and Frederick limestones. Bassler[10] followed this division of the limestones. In a report on granites of Maryland by Keyes and Williams,[11] published after the death of Williams, the general relation of the Sykesville granite is discussed. Recent publications covering part of Frederick and Carroll Counties include an article by Cloos,[12] in which the structure of the rocks is discussed.

WORK BY THE WRITERS

The survey of Carroll and Frederick Counties was carried on in parts of the years 1924 to 1936 by Anna Jonas Stose for the Maryland Geological Survey, and in 1929 to 1936 by George W. Stose of the U. S. Geological Survey. A brief paper by Jonas[13] dealt with the crystalline rocks. In 1936 the writers[14] published a revision of the classification of the limestones of the Frederick Valley. In 1939 steep-fold axes in the crystalline schists of Carroll and Frederick Counties were described by Jonas.[15] The age relation of the two series of pre-Cambrian rocks in the Catoctin Mountain-Blue Ridge anticlinorium in Maryland and Virginia and in the Mount Rogers anticlinorium in Virginia was discussed later by the writers.[16]

GENERAL GEOLOGY

The oldest rocks in Frederick County occur in the Middletown Valley in the core of the Middletown anticline. These rocks are a complex of altered hornblende diorite, granodiorite, and biotite granite gneiss. These early pre-Cambrian rocks are overlain by a series of volcanic rocks of late pre-Cambrian age, comprising tuffaceous and detrital sedimentary beds overlain by rhyolite and basalt flows. Lower Cambrian arenaceous sedimentary rocks, which form Catoctin and South Mountains, overlie the volcanic series. These Lower Cambrian rocks are the Loudoun forma-

[9] Keyes, C. R., Ordovician rocks of Maryland. Johns Hopkins Univ. Circ., 1890.

[10] Bassler, R. S., The Cambrian and Ordovician deposits of Maryland. Md. Geol. Survey, pp. 111–117, 1919.

[11] Keyes, C. R., Origin and relation of the central Maryland granites; Williams, G. H., General relations of the granitic rocks in the Middle Atlantic Piedmont Plateau. U. S. Geol. Surv., 15th Ann. Rept., pp. 657–737, 1895.

[12] Cloos, Ernst, Crustal shortening and axial divergence in the Appalachians of eastern Pennsylvania and Maryland. Geol. Soc. Amer. Bull., vol. 51, pp. 862–869, 1940.

[13] Jonas, Anna I., Pre-Cambrian rocks of the Western Piedmont of Maryland. Geol. Soc. Amer. Bull., vol. 35, pp. 355–364, 1924.

[14] Jonas, A. I., and Stose, George W., Age reclassification of the Frederick Valley (Maryland) limestones. Geol. Soc. Amer. Bull., vol. 47, pp. 1657–1674, 7 figs., 1936.

[15] Jonas, A. I., Tectonic studies in the crystalline schists of southeastern Pennsylvania and Maryland. Amer. Jour. Sci., vol. 34, pp. 364–388, 1937.

[16] Jonas, Anna I. and Stose, George W., Age relation of the pre-Cambrian rocks in the Catoctin Mountain-Blue Ridge and Mount Rogers anticlinoria in Virginia. Amer. Jour. Sci., vol. 237, pp. 575–593, 1939.

tion, Weverton quartzite, Harpers phyllite, and Antietam quartzite. In Catoctin Mountain the sequence of these Lower Cambrian rocks is, however, broken by a normal fault. The Antietam quartzite occurs only east of the fault, where it is overlain by Tomstown dolomite. Frederick Valley is underlain by limestones of Upper Cambrian and Lower Ordovician age, with the underlying Antietam quartzite exposed in anticlines.

Rocks of the Martic overthrust block lie east of the Frederick Valley. The oldest rock in this block is the Baltimore gneiss, exposed in the southeast corner of Carroll County, at the west end of the Woodstock anticline. The gneiss is a banded rock of granitic aspect which contains thin layers of hornblende gneiss, and is of early pre-Cambrian age. The Baltimore gneiss is overlain by the Setters formation, followed by the Cockeysville marble, Wissahickon schist, and Peters Creek formation. The Peters Creek formation is enclosed in the Peach Bottom syncline, which crosses the southeastern part of Carroll County. The Wissahickon and Peters Creek formations are intruded by hornblende gabbro and the Sykesville granite. North of Marriottsville the Cockeysville marble and Wissahickon formation are intruded by granitic pegmatite. West of the Peach Bottom syncline the albite-chlorite schist facies of the Wissahickon formation occupies a wide area. A series of volcanic rocks and marble, which extend to the western edge of the Martic overthrust block, lies west of the albite-chlorite schist. Quartzose rocks, which overlie the volcanic series, form Sugarloaf Mountain in the southern part of Frederick County and high hills near Wentz in the northern part of Carroll County.

Triassic conglomerates, red sandstones, and red shales cover the northeastern and central parts of Frederick County and the northwestern part of Carroll County, and unconformably overlie the rocks of the Martic overthrust block and the Paleozoic rocks of the Frederick Valley. This unconformity is exposed along the southeastern edge of the Triassic rocks. Their northwestern boundary is for the most part a normal fault, which has uplifted older rocks to the west.

The County Geological Maps

The Carroll County geologic map was published by the Maryland Geological Survey in 1928 and the Frederick County map in 1938. The Carroll County map was printed before the writers had completed their work in Frederick County and before they had mapped the adjacent area in Pennsylvania to the northeast and in Virginia to the southwest. The terminology and correlation on this map were tentative and do not conform with that shown on the Frederick County map nor with that of the map[17] of the adjacent York County, Pa., published in 1939. The revised terminology and mapping for the western part of Carroll County is included on the map of Frederick County.

The revised mapping of the geology of Carroll County east of the part printed on the Frederick County map is shown in figure 4. The description of the geology in

[17] Stose, Geo. W., and Jonas, Anna I., Geology and Mineral Resources of York County, Pennsylvania. Pa. Geol. Surv. Bull. C.67, 1939.

Stose, Anna J. and George W., Geology of the Hanover-York District, Pennsylvania. U. S. Geol. Surv. Prof. Paper 204, 1944.

this report conforms to the mapping shown on the Frederick County map and in figure 4. Furthermore, the mapping of the Cambrian quartzose formations in the southern part of South Mountain on the west edge of Frederick County and in the

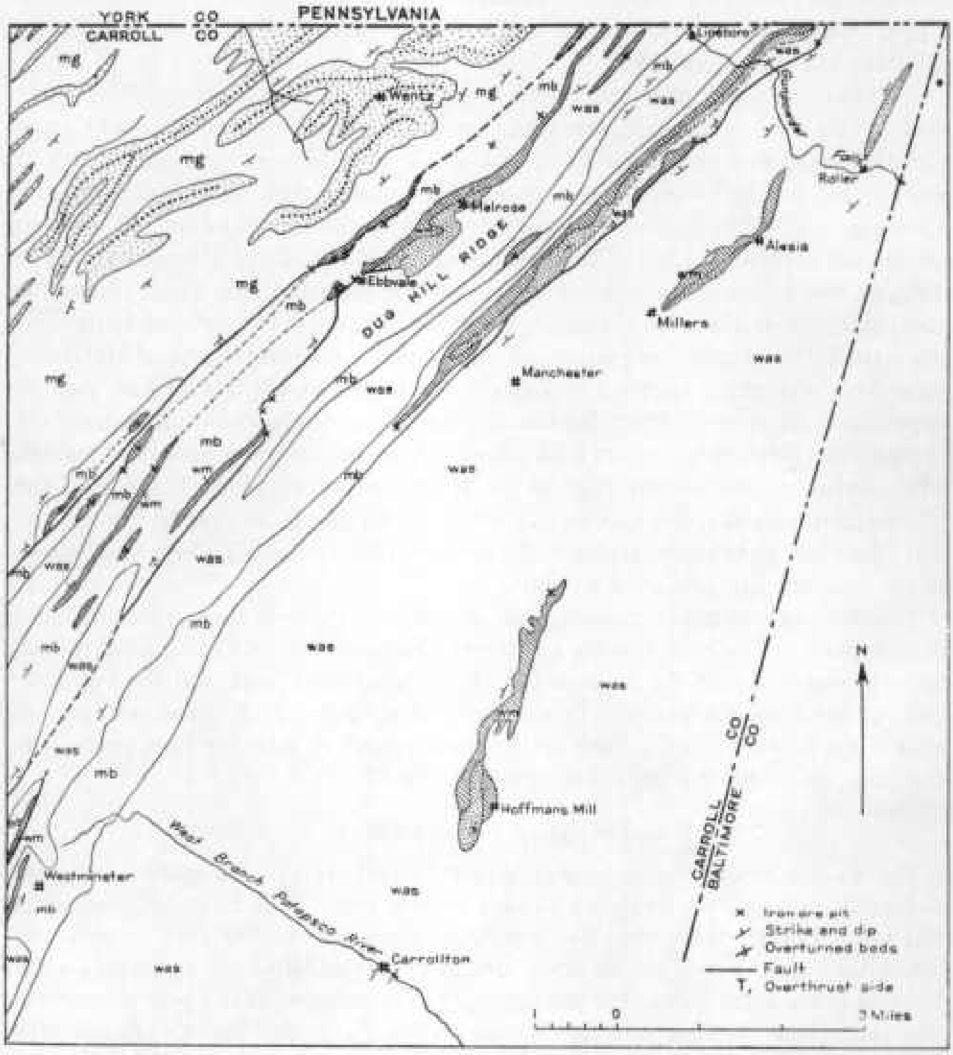

FIG. 4. Revised geologic map of the northeastern part of Carroll County, showing revised nomenclature to accord with that of the western part of the county printed on the Frederick County map. *was*, albite-chlorite schist facies of Wissahickon formation, with quartzite (dense stipple pattern) at base; *mg*, Marburg schist, with quartzite (light stipple pattern) and conglomerate (heavy dot pattern) at top; *mb*, Sams Creek metabasalt; *wm*, (ruled pattern) Wakefield marble.

adjacent part of Washington County printed on the Frederick County map has been somewhat revised by later field work, and the corrected mapping of South Mountain in Frederick County is shown in figure 5.

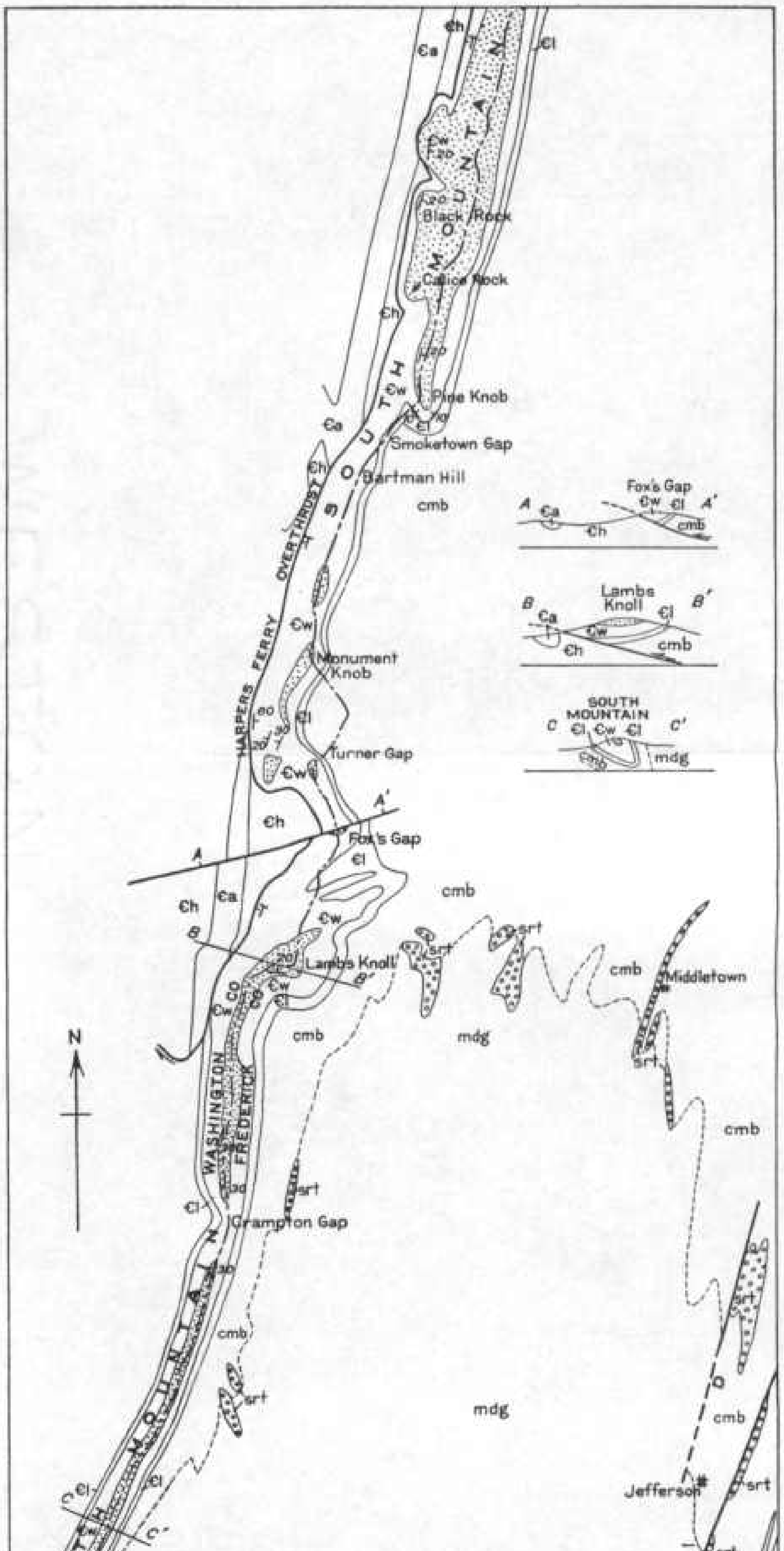

FIG. 5. Revised geologic map of the southern part of Frederick County. *mdg*, granite and granodiorite of the early pre-Cambrian injection complex; *srt*, Swift Run tuffaceous quartzose rocks and volcanic slate of later pre-Cambrian age; *cmb*, Catoctin metabasalt of late pre-Cambrian age; *ls*, limestone associated with metabasalt; *Ꞓl*, Loudoun formation; *Ꞓw*, Weverton quartzite, with upper cliff-making quartzite stippled; *Ꞓh*, Harpers phyllite; *Ꞓa*, Antietam quartzite.

P.14 B

The rocks in Frederick and Carroll Counties will be described under the following major headings: Pre-Cambrian rocks in the Blue Ridge-Catoctin Mountain anticlinorium, Paleozoic sedimentary rocks, crystalline rocks of the Piedmont upland, Triassic system.

PRE-CAMBRIAN ROCKS OF THE BLUE RIDGE-CATOCTIN MOUNTAIN ANTICLINORIUM

GENERAL DESCRIPTION AND LOCATION

Pre-Cambrian rocks, mostly of igneous origin, cross Frederick County in a belt 5 to 8 miles wide extending from the Pennsylvania State line on the north to the Potomac River at the south. In the northern part of the county, the pre-Cambrian rocks extend about 1 mile into Washington County. At the Potomac River they extend from Point of Rocks to a point 1 mile west of Knoxville. These pre-Cambrian rocks are bounded on the east and west by ridges formed of the overlying Lower Cambrian quartzites—Catoctin Mountain on the east and South Mountain on the west. In the northern part of Frederick County the pre-Cambrian rocks form mountains which are higher than the southern parts of the bounding ridges of Cambrian quartzites.

These pre-Cambrian rocks unconformably underlie the basal Cambrian Loudoun formation. They have been brought to the surface in anticlines of the Blue Ridge-Catoctin Mountain uplift. The Middletown anticline lies in Frederick County and the Rohrersville anticline, which is west of South Mountain, lies in Washington County. The pre-Cambrian rocks comprise two series. The older series consists of intrusive rocks of early pre-Cambrian age, which are exposed in the Middletown anticline south of Middletown. The younger pre-Cambrian rocks are a series of volcanic rocks that overlie the intrusive rocks. They form narrow belts on the sides of the anticline south of Middletown and entirely cover the older rocks north of Middletown where the anticline does not rise so high. Tuffaceous and sedimentary rocks are at the base of the volcanic series (Fig. 5). The two series of pre-Cambrian rocks are exposed also in the Rohrersville anticline in Washington County.

EARLY PRE-CAMBRIAN ROCKS

General Description

The rocks of early pre-Cambrian age are granitic gneisses which underlie an upland area in the Middletown Valley that extends southward from Middletown to Potomac River, a distance of 10 miles. The belt is $5\frac{1}{2}$ miles wide at the river. The upland is dissected by Catoctin and Little Catoctin Creeks, which empty into Potomac River. Most of the outcrops in this area are along the creeks and in road cuts near these streams. Outcrops are few on the upland where the rocks are deeply weathered. The granitic gneisses are cut by numerous dikes of green metadiabase, which is genetically related to the metabasalt of the late pre-Cambrian volcanic series. The dike rocks weather to hard rounded boulders which strew the upland surface, whereas the granitic rocks generally break down into soil. Because of the lack of outcrops, the metadiabase dikes have not been mapped separately from the granitic gneisses. The writers[18] have described briefly the intrusive rocks of the Middletown and Pleasant Valleys and their southward extension in Virginia, where they form the core of the Blue Ridge-Catoctin Mountain anticlinorium, and referred to them as the injection complex. This term will, therefore, be used for these intrusive rocks in this report.

On the Frederick County geologic map the injection complex is mapped as mica schist and hornblende diorite, intruded by granite and granodiorite. Granodiorite, the more widespread type of rock in Maryland, is a fine-grained light-gray to pale-green gneissic rock, in places interlayered with dark hornblende diorite. Biotite granite gneiss and augen gneiss with mica schist layers crop out in places along Catoctin Creek on the east side of the belt.

Granodiorite

The granodiorite contains white and dull-green feldspar, green hornblende, and chlorite. In places it is mottled by dark aggregates of fine hornblende, biotite, and chlorite. It is veined by quartz, epidote, and sericite. In thin section the granodiorite is seen to contain phenocrysts of microcline, partly replaced by albite, and perthite with sericitized rods. Plagioclase, of the composition of calcic oligoclase, is saussuritized and in places is surrounded by a border of clear albite. Quartz of the groundmass is strained. The dark constituents comprise fine blades of hornblende, biotite, chlorite, and epidote. They are probably secondary to original pyroxene. Accessory minerals are zircon, magnetite, and ilmenite. In some specimens fine hematite dust clouds the potash feldspars, and in hand specimens such feldspars are pale pink. Large potash feldspars in the granodiorite contain inclusions of quartz and sericitized feldspars, hence they are not phenocrysts which crystallized before the constituents of the ground mass. The rest of the rock has the composition of a diorite in which the original pyroxene has altered to hornblende and epidote. The potash feldspars may have been formed by the introduction of granitic solutions which replaced the plagioclase with concomitant development of myrmekite and formed clear rims around the plagioclase. Biotite was developed from pyroxene or hornblende by hydrothermal action of the potash-bearing solutions.

Biotite Granite Gneiss

In the southeastern part of the Middletown Valley, biotite granite gneiss is the prevailing type of intrusive rock, and it is well exposed along Catoctin Creek 3 miles northeast of Brunswick. It is a dark biotitic granite gneiss with included biotite schist bands. The gneiss is composed of layers of fine crinkled blades of black biotite mottled by irregular patches of white and pale-green feldspar and blue quartz. In outcrops near Catoctin Creek on U. S. Highway 340, the granite gneiss shows a strong secondary layering made up of shiny biotite and muscovite blades which bend around lenses of feldspar and blue quartz.

In thin section the constituents of the biotite granite gneiss are microperthite, saussuritized plagioclase with clear-growth borders of albite, myrmekite, and strained

[18] Jonas, Anna I., and Stose, G. W., op. cit. Am. Jour. Sci., vol. 237, pp. 575–593, figs. 1 and 2, 1939.

quartz. The biotite blades are dark green and finely crinkled, and do not lie parallel to any parting plane but are in aggregates with grains of epidote, zoisite, and apatite. Ilmenite is altered to leucoxene. The muscovite-biotite gneiss exposed near Catoctin Creek on U. S. Highway 340 shows green biotite and muscovite and pale-green chlorite, which form the schistose planes and bend around lenses composed of perthite, altered plagioclase, and myrmekite. The plagioclase has clear borders of albite. The perthite includes quartz grains. Quartz grains occur in large patches and the quartz is strained. Garnets, where present, are much broken, and green biotite has grown in the cracks. The muscovite-biotite gneiss differs from the biotite granite gneiss in that it is more sheared; muscovite has replaced biotite and the platy minerals are smeared out on the parting planes; the feldspars are granulated on their borders and garnets are cracked. The muscovite-biotite gneiss is a part of the biotite granite gneiss which has been rendered schistose by late Paleozoic deformation, for its schistose planes conform to those in the Paleozoic rocks of the region.

Relative Age of Granodiorite and Biotite Granite Gneiss

In Frederick County the injection complex crops out in a small area and contains a secondary schistosity which obscures the primary structures. The age relations of the rock types of the injection complex, therefore, cannot be determined there. Similar rocks, stratigraphically continuous with those of the Middletown anticline, form the core of the Blue Ridge uplift in Virginia, where they cover wide areas and are better exposed. In northern Virginia the writers have established the general sequence of the formations of the injection complex, and have mapped them in detail in southern Virginia where they are exposed in the Elk Creek anticline[19] of Grayson County.

The Elk Creek anticline is in the Blue Ridge Plateau of southwestern Virginia, a region of high mountains and fresh rock exposures. The oldest rock of the injection complex is a highly metamorphosed biotite gneiss with layers of biotite schist and quartzite—the Saddle gneiss. It is intruded by diorite, which, in most of its extent, is altered to hornblende diorite—the Cattron diorite. Both the Saddle gneiss and Cattron diorite have been injected, intruded, and replaced by a series of granitic intrusions; earlier intrusions are seen to be cut by those of later age. The earliest of these intrusions is a white aplitic granite which injected the biotite gneiss to form a highly contorted ribbon gneiss, or replaced it to form a biotite augen gneiss. The white aplite intruded the diorite as a fracture pegmatite in a complicated network. Biotite-quartz monzonite—the Point Lookout granite of the Elk Creek anticline and Lovingston granite gneiss of northern Virginia—intruded the complex as large concordant bodies. Pink pegmatitic granite of still later age—the Carsonville granite of the Elk Creek anticline—injected and replaced the older rocks just described. In places pink pegmatite cuts across Cattron diorite that contains intrusions of white aplite and also cuts the Point Lookout granite. The pink granite replaces Saddle gneiss to form a biotite gneiss with pink microcline metacrysts. By metasomatic replacement, the diorite has become a hypersthene granodiorite with

[19] Jonas, Anna I., and Stose, George W., Geology and Mineral Resources of the Gossan Lead and adjacent area in Virginia. Va. Geol. Surv. (in course of publication).

microcline metacrysts which contain inclusions of andesine, hypersthene, and other primary minerals of the diorite. In the Elk Creek anticline, this mixed rock is the Grayson augen granite gneiss. The pink pegmatite also has replaced the diorite, so that there are all gradations from diorite to pink granite with scanty hornblende crystals.

The biotite granite gneiss in Frederick County has the composition of a quartz monzonite and resembles the Lovingston granite gneiss which is widely distributed to the southwestward in the eastern part of the Blue Ridge-Catoctin Mountain uplift in Virginia. The biotite granite gneiss contains included bands of biotite schist which appear to represent the Saddle gneiss, the oldest rock of the injection complex in Virginia.

The granodiorite of the Middletown anticline, as was stated above, is regarded as a diorite which has been replaced by potash-bearing and soda-bearing solutions. Although the granodiorite contains no original pyroxene, it appears to be a facies of the hypersthene granodiorite of the Virginia Blue Ridge area. The diorite, which was later replaced to form the granodiorite, probably is the Cattron diorite, and hence is younger than the biotite gneiss which was invaded by granite and now is exposed in the southeastern part of the Middletown anticline.

LATE PRE-CAMBRIAN VOLCANIC SERIES

General Description

The late pre-Cambrian volcanic series comprises Catoctin metabasalt, aporhyolite, and rhyolitic tuff with sericitic quartzite at the base. These rocks overlie the injection complex on both sides of the Middletown Valley and pass around the north end of the uplift and extend northward to the Maryland-Pennsylvania State line. On the east side, the volcanic rocks are overlain by the Loudoun formation and Weverton quartzite of Catoctin Mountain, and on the west side by the same formations in South Mountain. The volcanic rocks are folded and are schistose in places but the volcanic textures have not been entirely destroyed.

Swift Run Tuff

At the base of the Catoctin metabasalt is a series of detrital quartzite and tuffaceous slate which lies directly on the older injection complex (Fig. 5). This sedimentary and volcanic formation is named the Swift Run tuff from outcrops exposed on U. S. Highway 33 just east of Swift Run Gap, Va., and on the Skyline Drive just north of the gap.[20]

In Frederick County the Swift Run tuff forms a discontinuous line of low hills from a point 3 miles southwest of Burkittsville northeastward to Everhart School and eastward nearly to Middletown. South of Middletown it extends to Jefferson, where it is cut off by a fault. The beds comprise blue and green bleby tuff, sericite schist, and a sericitic quartzite with glassy and blue quartz grains. The grains are subangular and are up to $\frac{1}{4}$ inch in size, and are detrital. The sericitic quartzite in

[20] Jonas, Anna I., Stose, G. W., op. cit. Amer. Jour. Sci., 5th Ser., vol. 237, pp. 575–593. Pl. 1, figs. 1–2, 1939.

the areas south of Burkittsville, west of Middletown, and east and north of Jefferson, now included in the Swift Run tuff, was shown on the Frederick County geologic map as Loudoun formation. At these places the rock lies at the contact of the Catoctin metabasalt with the injection complex, and formerly was believed to be infolds of overlying Loudoun formation. On the Harpers Ferry geologic map Keith[21] mapped four areas of sericitic quartzite in the Middletown uplift, which are also shown on the Frederick County map, and he called them Loudoun formation. However, Keith recognized a difference between the Loudoun that he mapped within the granite and basalt areas and the type of Loudoun associated with the Weverton quartzite, and states that this difference "raises the question of the unity of the formation."

An area of rhyolitic tuff east of Compton Gap and three areas in the vicinity of Middletown, which also lie at the contact of the metabasalt with the injection complex and are now included in the Swift Run tuff, were mapped as rhyolite tuff on the Frederick County map. North of Bolivar, volcanic slate of the Swift Run tuff is apparently brought to the surface in an anticline. Other lenticular bodies of tuffaceous slate in the Catoctin metabasalt farther north may be tuffaceous beds within the metabasalt.

Since the publication of the Frederick County map, the writers have done additional work in Maryland, in Clarke and Loudoun Counties, Virginia, and farther south in the Blue Ridge-Catoctin Mountain uplift, and have found that sedimentary and tuffaceous beds persistently lie at the contact of the injection complex with the Catoctin metabasalt, and have concluded that they are the basal part of the late pre-Cambrian volcanic series which rests on the older injection complex and are not lenticular infolds of Loudoun formation (Fig. 5).

Marble.—Marble crops out for a distance of one mile north of Potomac River in the valley of a small stream just east of Catoctin Station on the Baltimore and Ohio Railroad. The marble is medium grained, crystalline, and white, and includes layers of muscovite-chlorite schist. It strikes N.10° E. and dips 30° SE. under the Catoctin metabasalt. Schistose granodiorite crops out in the railroad cut west of the marble, suggesting a fault between the marble and the granodiorite. This is in strike with a fault shown on the Frederick County geologic map on the west side of lenticular areas of sericitic quartzite of the Swift Run tuff south and east of Jefferson.

The marble extends southwestward into Virginia, where it is exposed at intervals along this strike on the west border of the Catoctin metabasalt for a distance of 40 miles. The marble is well exposed at Taylorsville, Va., 3½ miles southwest of Frederick County, and farther southwest near Goose Creek, 3 miles west of Oatlands, where it has been quarried. At Taylorsville the marble underlies the Catoctin metabasalt and lies east of granitic rocks of the injection complex. At Goose Creek the marble is interbedded or infolded with the Catoctin metabasalt. In the quarry on Goose Creek, quartzite dips 30° E. under the marble, and overlies the injection complex. The quartzite is exposed for a mile along its strike and thickens southwestward. The lower beds consist of coarse arkose and conglomerate made up of fragments of

[21] Keith, Arthur, op. cit., Harpers Ferry folio, U. S. Geol. Surv., 1894.

the injection complex and grains of blue quartz characteristic of the injection complex of that area. In Virginia and Maryland Keith[22] mapped the marble and associated quartzite as Loudoun formation. It is the writers' opinion that the marble is part of the Swift Run tuff and lies just above basal quartzose beds.

Catoctin Metabasalt

Distribution.—The Catoctin metabasalt in Frederick County is exposed in the mountainous area between South and Catoctin Mountains. In the northern half of the county it forms a belt 5 to 6 miles wide in which are included several infolded belts up to a mile in width of aporhyolite. South of U. S. Highway 40, the metabasalt is largely restricted to two narrow belts adjacent respectively to South and Catoctin Mountains, which border the early pre-Cambrian injection complex. The Catoctin metabasalt forms rough country with craggy outcrops along the summits of the ridges and in narrow valleys which are largely wooded. It is deeply weathered on the upland surface, where it makes good farm land.

Character.—The Catoctin metabasalt includes massive green lava flows, which are amygdular and have flow banding, hornblende schist, and tuffaceous beds. The latter are separately mapped as rhyolite tuff. Two miles northeast of Wolfville a blue andesite, which is separately mapped, is regarded as part of the Catoctin flows.

The metabasalt is a dense, hard, green rock composed of hornblende, epidote, and feldspar laths, which are usually of microscopic size. No glass is now present in the basalt, and most of the original minerals have been replaced. Pyroxene is largely replaced by hornblende, epidote, or chlorite; calcic feldspar by epidote, zoisite, and a more sodic feldspar. Ilmenite is altered to leucoxene. The basaltic structure is frequently preserved, and under the microscope the ophitic network of feldspar laths and, in some cases, the form of interstitial pyroxene, are still visible. Much of the basalt is amygdular (Pl. 4A), and the vesicles are filled by secondary minerals, of which quartz, epidote, and chlorite are the most abundant, and calcite, jasper, and pink feldspar are of common occurrence. Green chlorite may surround a center made up of white quartz and green epidote; white quartz, or pink feldspar, may surround radiating clusters of bright-green epidote. Piedmontite, the red manganese-bearing epidote, occurs in amygdules 2 miles east of Wolfville. The amygdular rock, when polished, makes a striking appearance because of the pleasing contrast of bright colors of the minerals filling the vesicles with the somber dark green of the groundmass. The amygdules are spherical, or are elongated by the flow of the lava or by metamorphism. Quartz and epidote have replaced the basalt in large part, and this resultant hard epidotite rock, by differential weathering, stands out as rough knots on the basalt surface, and residual blocks of it strew the ground. Where the minerals in the vesicles have been removed by weathering, the basalt is full of rust-stained holes. Quartz and epidote vein the basalt in many places. Flow banding is commonly visible in the massive basalt, but in the softer layers southeast-dipping schistosity is prominent and has destroyed the primary structures. Flow breccia, exposed east of Monument Knob, is composed of blocks of flow-banded basalt,

[22] Keith, A., op. cit. Catoctin Belt, U. S. Geol. Surv., 14th Ann. Rept., 1895.

veined with red jasper, enclosed in a ferruginous basaltic matrix containing red jasper and epidote.

Some of the basalt is softer dark-green amphibolite schist which is less resistant to erosion than the vesicular basalt. Some of the amphibolite schist contains flattened blebs or shiny green streaks of chlorite, indicating derivation from a vesicular lava or tuff that has been deformed by later pressure. Thin veins of asbestos with associated malachite and azurite occur in the metabasalt north of Sensenbaugh School.

Blue amygdular metaandesite forms a narrow belt 6 miles long west of a body of aporhyolite and east of the Loudoun formation of South Mountain. The southern end of the andesite is crossed by a road $1\frac{1}{2}$ miles west of Wolfville. The rock is fine grained, dense, and dark blue, and contains amygdules which range in diameter from $\frac{1}{8}$ of an inch to $1\frac{1}{2}$ inches. In thin section the rock is composed of fine grains of quartz, saussuritized plagioclase laths, epidote grains, and pale-green actinolite fibers. It has an ophitic texture and is dusted with fine magnetite, the presence of which gives the rock its bluish color. The vesicles have an outer border of pale-green chlorite and epidote, which radiate from the walls. Feldspar and quartz fill the centers of the vesicles. Some are entirely filled with green epidote. West of Sensenbaugh School the large amygdules contain, in addition, the red epidote, piedmontite. Some amygdules contain also the rare reddish-brown mineral, homilite, a lime-iron silicate containing boron.

Analyses of Metabasalt from South Mountain, Pa.

A		B	
SiO_2	48.02	SiO_2	51.89
Al_2O_3	17.84	Al_2O_3	15.28
Fe_2O_3	11.61	Fe_2O_3	3.10
FeO	.98	FeO	3.60
CaO	18.25	MgO	8.68
P_2O_5	1.45	CaO	7.38
Ignition	1.50	Na_2O	3.27
	——	K_2O	2.57
	99.65	H_2O^+	1.17
		H_2O^-	1.37
		TiO_2	.91
		P_2O_5	.61
		V_2O_3	
		MnO	.12
		NiO	.02
		BaO	.15
		SrO	.09
		Si_2O	trace
		Fe_2S	—
			100.21

A.—Epidote rock, $2\frac{1}{4}$ mile south of Mt. Alto Furnace. Analyst, F. A. Genth. P. Frazer, Pa. Geol. Surv. CCC, p. 264, 1877.

B.—Catoctin schist. Bechtel Copper Shaft, South Mountain, Pa. Analysis by C. H. Henderson. Idem. p. 307, quoted from Williams, G. H., Trans. Am.Inst. Min. Eng., vol. XII, p. 82.

At Church Hill, $\frac{1}{2}$ mile west of Ellerton, dense blue felsitic rock occurs as a dike in the Catoctin metabasalt. The dike is about 50 feet wide with vertical walls, and has epidote on the joints. St. Johns Lutheran Church, at Church Hill, is built of this rock. In thin section it is made up of feldspar laths, fine grains of quartz, epidote, and ilmenite, and is dusted with iron oxide. Its composition seems to relate it genetically to the andesite, although it is shown on the county map as rhyolite tuff. Since the dike cuts the metabasalt, the andesite may be a late stage of basaltic flow, younger than the main body of the Catoctin metabasalt.

No analyses of the Catoctin metabasalt in Frederick County are available, but analyses of the same rock from South Mountain in the adjacent part of Pennsylvania are given in the table shown on page 21.

Tuffaceous beds, mapped as rhyolite tuff on the Frederick County map, occur throughout the area of Catoctin metabasalt from the vicinity of Middletown northward to near Myersville. The tuff comprises blue and green slate spotted with flattened blebs, blue and buff sericitic slate, sericitic quartz schist, and soft olive-green sericitic slate. These tuffaceous beds are well exposed on the Myersville-Harmony-Tyler School highway. For a distance of 4 miles at and west of Tyler School, the tuff beds appear to be interbedded with the metabasalt, but they may be infolded in that lava. The beds strike north or north-northwest. Minor folds are overturned to the southwest and pitch 20°–45° SE.

Aporhyolite and Associated Pyroclastic Sediments

Distribution.—In the northern part of the Middletown anticline, aporhyolite crops out in two north-trending belts. The eastern body is nearly 2 miles wide, from the vicinity of Middlepoint northward to beyond Foxville. It ends northeastward in two narrow tapering bands, the longest of which extends $1\frac{1}{2}$ miles northeast of Sabillasville. South of this main body an outlying mass of aporhyolite occurs at Miller Hill. The western body begins just southeast of Pine Knob and extends north along the east foot of South Mountain. At Sensenbaugh School this body of aporhyolite branches into two narrow bands which pass northward into Washington County. The eastern of these two bands enters Frederick County again to the north and nearly reaches the Maryland-Pennsylvania State line. A small outlying area of aporhyolite lies east of the northeast end of Catoctin Mountain, west of the Triassic border fault and south of Turkey Creek. The aporhyolite bodies are entirely surrounded by Catoctin metabasalt except in the area near Pine Knob where it is overlain on the west side by the Loudoun formation on the east flank of South Mountain.

Character.—The aporhyolite in large part is a dense, gray to blue cryptocrystalline rock with phenocrysts of white feldspar and glassy quartz. Pink porphyritic rhyolite occurs in the western belt and has been separately mapped. Flow breccia and pyroclastic sediments occur at the contact of the rhyolite with metabasalt near Middlepoint and south of Pine Knob.

The dense gray-blue aporhyolite is a hard brittle rock which breaks with a conchoidal fracture. It weathers to light-gray angular slabs which are in common use for stone fences and foundation stones. Flow banding and other characteristic volcanic structures are brought out on weathered surfaces (Pl. 5). The original constituents and textures of the lava show that they belong to the rhyolite family, but they are called aporhyolite because of their alteration and devitrification. The original glassy base of the lava has been altered to a groundmass with granular or micropoikilitic fabric. The aporhyolite shows textures found in younger lavas, such as flow banding, flow breccia, and spherulitic texture.

In thin section, the grayish-blue aporhyolite has a micropoikilitic fabric, with phenocrysts of potash feldspar and quartz in a cryptocrystalline groundmass of quartz and feldspar with black iron oxide dust. The phenocrysts are orthoclase and perthite, largely with crystal outline. The rock is cut by veins of sericite and epidote. In places the aporhyolite has minute spherulites developed in roughly parallel planes, in cross section giving the appearance of beads on a chain (Pl. 5B).

Rhyolite flow breccia has been observed at the contact of the rhyolite with the metabasalt at the south border of the eastern belt of rhyolite near Middlepoint and in small outlying areas west of Five Forks and at Miller Hill. In places tuff breccia and white sericitic tuffaceous slate are associated with the flow breccia. The flow breccia is made up of angular fragments of dense blue rhyolite in a felsitic matrix, with a marked flow banding. The fragments range in size from microscopic dimensions to several inches in diameter, and weather to a lighter color than the matrix (Pl. 4B). The breccias were formed by the breaking up of solidified cooled portions of the magma during movement of the viscous mass.

Red porphyritic aporhyolite occurs in two areas in the western belt of aporhyolite. The northern area is near Sensenbaugh School and the southern area is south and north of Wolfville Crossing. The red aporhyolite is at the contact of the aporhyolite with the metabasalt, and in the southern area it is associated with rhyolite tuff. The red aporhyolite has a dense red groundmass with phenocrysts of pink feldspar and glassy quartz. Hematite and piedmontite grains are visible to the naked eye in hand specimens. In thin section the body of the rock shows a finely granular quartz and feldspar mosaic dusted with hematite. The feldspar phenocrysts are sericitized perthite. Spherulites are replaced by potash feldspar, which has centers of hematite and piedmontite. The red color is due to the presence of hematite dust and grains of piedmontite. In Pennsylvania[23] piedmontite occurs macroscopically in the aporhyolite. It is especially abundant near Monterey, Pa., and in Buchanan Valley, where Williams attributed the red color of the aporhyolite to the presence of the manganese epidote, piedmontite. It occurs there as specks disseminated through the rock, in fine radiating needles filling vesicular cavities, and in veins and crack fillings.[24]

No analyses of aporhyolite from Frederick County are available, but two analyses of similar rock from Monterey and Blue Ridge Summit, in the adjacent part of Pennsylvania, are given in the following table.

[23] Williams, G. H., loc. cit. Amer. Jour. Sci., vol. 44, p. 495, 1892, and vol. 46, pp. 50–57, 1893.

[24] Stose, G. W., Fairfield-Gettysburg folio, U. S. Geol. Surv. Geologic Atlas No. 225, pp. 4–5, 1929.

Analyses of Aporhyolite from South Mountain, Pa.

	A	*B*
SiO_2	76.34	73.85
Al_2O_3	11.60	13.15
Fe_2O_3	2.41	3.27
FeO	.30	.36
MgO	.06	.32
CaO	.55	.82
Na_2O	5.50	2.29
K_2O	2.75	5.42
H_2O^+	.10	.71
H_2O^-	.39	
TiO_2	.26	—
CO_2	trace	—
P_2O_5	trace	.06
MnO	trace	.09
BaO	.09	—
	100.35	100.34

A.—Aporhyolite, Monterey, Franklin County, Pa. Analyst, H. N. Stokes, U. S. Geol. Surv. Bull. 150, p. 348, 1898.

B.—Quartz porphyry, same locality. Analyst, L. G. Eakins, U. S. Geol. Surv. Bull. 148, p. 81, 1897.

Pyroclastic Sediments.—The aporhyolite has associated with it pyroclastic sediments, which are best displayed at the south ends of both belts of aporhyolite. Some of the larger areas are shown on the county geologic map. Aporhyolite flow breccia in the area ½ mile west of Five Forks has associated with it tuff breccia which is interbedded with blue slaty tuff. The tuff breccia is made up of grains of quartz and epidote with angular fragments of aporhyolite in a sericitic quartzose matrix. Under the microscope the aporhyolite fragments are seen to be vesicular. Blue slate and white sericitic schist of tuffaceous origin border the blue aporhyolite south of Middlepoint.

Pyroclastic sediments south of Pine Knob comprise a series of green banded slate, bluish gray tuff with elongated blebs, dense gray slate with glassy quartz grains, and schistose bluish-gray tuff with drawn-out lenses of white finely granular quartz. The tuffaceous layers are interbedded with blue vesicular aporhyolite with quartz-filled vesicles and a purple aporhyolite containing feldspar phenocrysts up to ⅛ inch in length. This series of pyroclastics and flows is folded, the layers are crinkled and broken by cleavage which dips 60° SE., and the folds pitch north. The pyroclastic beds pass northward into red aporhyolite. East of the main belt of the pyroclastics thin layers of similar tuffaceous beds are apparently interbedded in the metabasalt.

Dike Rocks

The injection complex of the Middletown Valley is cut by numerous dikes of metadiabase which range from 1 foot to 75 feet in thickness. Their general strike is northeast. The dikes have not been mapped because of poor exposures. The massive diabase of thicker dikes weathers to rounded boulders that strew the surface. The diabase of thinner dikes is altered to hornblende schist which weathers readily to soil.

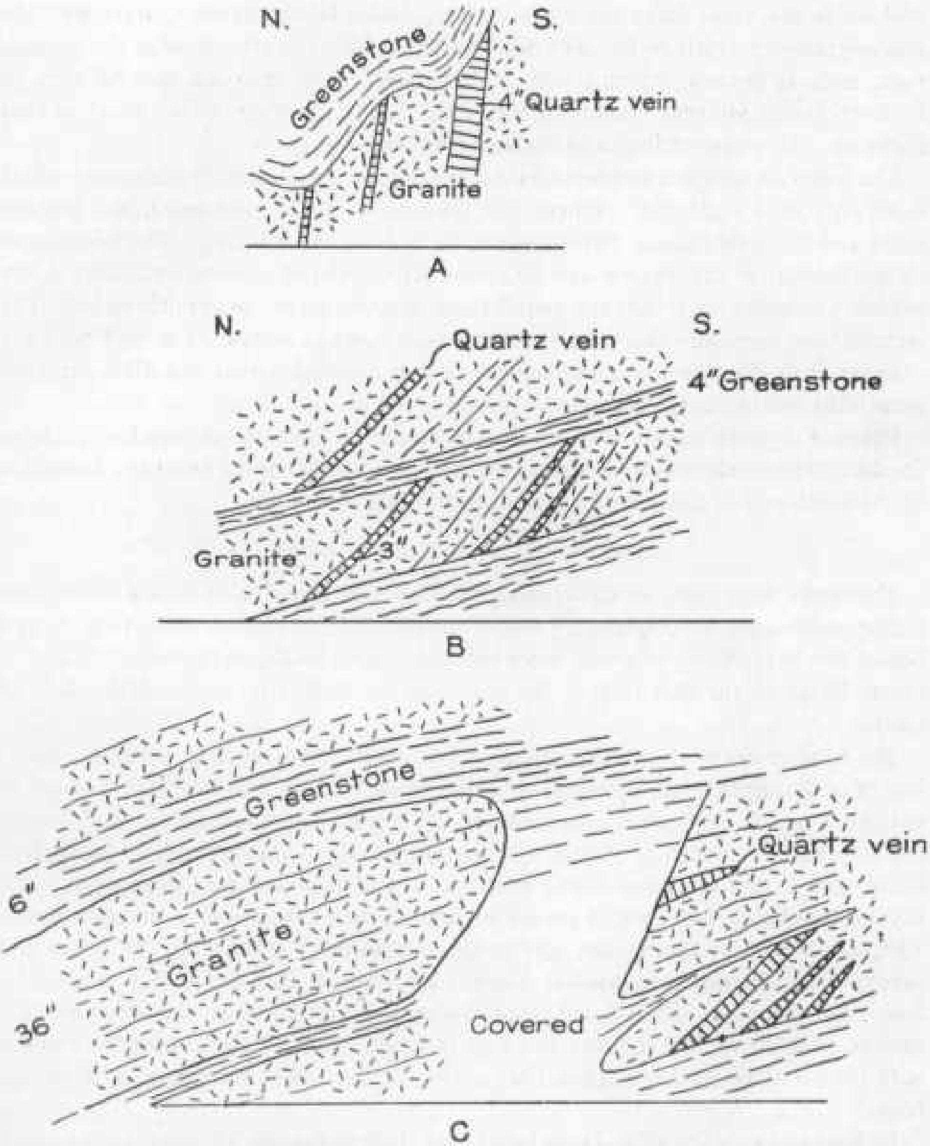

FIG. 6. Metadiabase sills and dikes cutting granite of the injection complex. Catoctin Creek, 2 miles west of Jefferson. A, B, C. Metadiabase (greenstone) sills truncating quartz veins following old joint fractures in the granite. C. Shows later cleavage common to granite and greenstone.

The massive diabase has an ophitic texture. Augite, in part altered to hornblende, fills the spaces between automorphic laths of saussuritized plagioclase. Other constituents are actinolite, felty chlorite, epidote, and ilmenite altered to leucoxene. The diabase of thinner dikes is altered to hornblende schist in which no augite has been seen. This rock is made up of saussuritized feldspar, green hornblende, epidote, chlorite or clinoclore, fine quartz grains, and in places pyrite and magnetite. The diabase in the wider dikes has a fine-grained chilled border at the contact with the coarse-grained granitic rock. The dikes truncate the older structures in the granitic rock, such as gneissic layering and quartz veins. Such relations may be seen on U. S. Highway 340 near Catoctin Creek (Fig. 6) and elsewhere to the south of that highway. In places stringers of diabase penetrate the gneiss.

The injection complex and metadiabase dikes have a well-defined schistosity which commonly dips southeast. Where this schistosity is well developed, the granitic rocks and the metadiabase may appear to be in concordant layers. The presence of chilled borders in the diabase and its cross-cutting relations to the structures in the injection complex show that the metadiabase is intrusive in the granitic rocks. The metadiabase resembles the Catoctin metabasalt flows in composition, and both are younger than the injection complex; hence it is concluded that the dikes are syngenetically related to the metabasalt flows.

Dikes of rhyolitic composition are rare in Frederick County. A blue felsitic rhyolite dike 20 feet wide cuts the Catoctin metabasalt just west of the Loudoun formation at the south end of Catoctin Mountain west of Point of Rocks.

Relative Age of the Volcanic Rocks

The Swift Run tuff, which overlies the injection complex, makes a corrugated border around the north-plunging end of the anticline of granitic rocks (Fig. 5) and lies at the base of the volcanic series beneath the Catoctin metabasalt. Near Potomac River on the east limb of the anticline, the Swift Run tuff contains beds of marble.

The relative age of the metabasalt and aporhyolite is not so clear. The elongated bodies of aporhyolite are surrounded by metabasalt and might be either exposed in anticlines and lie beneath the metabasalt, or be enclosed in synclines and overlie the metabasalt. South of Pine Knob the minor folds in the pyroclastic rocks pitch north, away from the surrounding metabasalt, and this structure suggests that the rhyolites and pyroclastic rocks are enclosed in a syncline and overlie the metabasalt. The presence of an aporhyolite dike in the metabasalt west of Point of Rocks and other similar dikes in metabasalt in Virginia also indicate that the rhyolite is the later flow. On the other hand, flow breccia, volcanic breccia, and pyroclastic rocks are surface phenomena and indicate the tops of flows. Since they lie near the contact with the metabasalt, they suggest that the aporhyolite extrusion preceded the metabasalt.

In Pennsylvania Stose[25] has concluded that the aporhyolite is older than the metabasalt, a view in accord with that of Keith[26] for the Maryland area. Stose based his opinion in part on the fact that in places the aporhyolite adjacent to the metabasalt has a brick-red color, possibly due to oxidation of the iron in the aporhyolite by the molten basalt. Fragments of aporhyolite enclosed in the metabasalt 1 mile north of Gladhill, Pa., also have a brick-red color. The rhyolitic tuff and volcanic breccia in Buchanan Valley, Pa., overlie the aporhyolite flows, and represent the closing stage of the rhyolitic eruption. Stose's conclusion for the Pennsylvania area is that rhyo-

[25] Stose, G. W., Fairfield-Gettysburg folio, U. S. Geol. Surv. Atlas No. 225, pp. 4–5, 1929.

[26] Keith, A., Geology of Catoctin Belt, op. cit., pp. 313–315, 1895.

litic lava was erupted first, followed in places by rhyolitic tuff and breccia, and that near the end of the eruptions of rhyolite thin basalt flows alternated with the rhyolite, and eventually the basalt flows predominated. If the aporhyolite is older than the metabasalt, it occupies the same position as the tuffaceous beds in the Swift Run tuff which also underlies the Catoctin metabasalt and probably represents the southward thinning edge of the aporhyolite flows.

Relation of the Volcanic Rocks to the Injection Complex

In the Middletown anticline the volcanic series, with the Swift Run tuff at the base, surrounds the injection complex on the flanks and the north end of the anticline. The contact of the Swift Run tuff and the injection complex is not exposed in the Middletown anticline, but this contact is clearly exposed in Virginia east of Swift Run Gap where it is evident that the Swift Run tuff and Catoctin metabasalt overlie the injection complex.

Keith[27] concluded that the granitic rocks intrude the lava flows, and this view was expressed also in the geologic map of Virginia published by the Virginia Geological Survey in 1928. Furcron,[28] as a result of his study of the pre-Cambrian rocks of the Shenandoah Park, also believed that the granodiorite and granite intrude the Catoctin metabasalt. He states that granodiorite appears to intrude Catoctin metabasalt at several places in that region. The writers have seen no outcrop in Virginia or Maryland where pre-Cambrian granitic rocks intrude the metabasalt. They believe that the metabasalt overlies the granitic rocks.

More recently Cloos[29] states that, in the Middletown Valley in southern Maryland the granite intrudes the volcanic rocks in sill-like dikes which dip gently eastward and entered the volcanic rocks along the cleavage planes. His Figure 29 illustrates such "sill-like intrusions of granodiorite" from outcrops in a railroad cut west of Weverton, Washington County. This place is in the Rohrersville anticline. However in the legend on the geologic map of Washington County, published in 1941, Cloos does not include granodiorite in the Catoctin metabasalt. Granite and granodiorite are exposed at many places in the center of the Rohrersville anticline from a point one mile north of Gapland southwestward to Potomac River. These intrusive rocks are easily distinguishable from the metabasalt by their color, mineral content, and structural characters. In southern Maryland and in Virginia the volcanic and granitic rocks have a cleavage that is common to both series. This cleavage, as has been stated, is of late Paleozoic age (post-Conestoga according to Cloos), and the so-called sill-like dikes of granite, as described by Cloos, should, therefore, be of late Paleozoic age if, as he states, the path of intrusion was controlled by the cleavage direction. However, it is shown in Figure 6 that the metadiabase truncates the gneissic layering and quartz veins of the injection complex in the form of dikes or sills intruded into the granitic rocks and that they are not volcanic rocks intruded by

[27] Keith, A., Idem. Pl. 22, pp. 314–318, 1892.

[28] Furcron, A. S., Igneous rocks of the Shenandoah National Park area. Jour. Geol., Vol. XLII, No. 4, pp. 406–407, 1934.

[29] Cloos, Ernst, and Hietanen, Anna, Geology of the "Martic Overthrust" and the Glenarm series n Pennsylvania and Maryland. Geol. Soc. Amer. Special papers, No. 35, pp. 80 and 83, fig. 29, 1941.

granite. In a large part of the Blue Ridge-Catoctin Mountain uplift in Virginia, south of the Middletown Valley, Paleozoic deformation was not so intense and the outcrops are more numerous. There the injection complex is cut by diabase dikes, innumerable outcrops of which show clean-cut contacts with the injection complex. The diabase of the dikes frequently has a fine-grained chilled border at the contact with the granitic rocks, whereas the latter are coarse-grained at the contact; also the diabase truncates older structures in the injection complex. A good exposure of a diabase dike cutting across granitic rocks occurs on U. S. Highway 50, 5 miles east of Ashby Gap, Va., where the dike is 70 feet thick and its contact with the granitic rocks dips 50° east. In Virginia also the tuffaceous series contains pebbles and cobbles of the underlying granitic rocks. The Lynchburg gneiss, which underlies the Catoctin metabasalt on the east flank of the Blue Ridge uplift in Virginia, represents beds equivalent to the Swift Run tuff. The gneiss has at its base the Rockfish conglomerate, which is made up of granitic pebbles and cobbles derived from the underlying injection complex.

For the following reasons the writers conclude that the volcanic rocks were deposited and extruded on a floor made up of the much older injection complex:—the volcanic rocks are not intruded by granite; the Swift Run tuff rests on granodiorite of the injection complex with a sedimentary contact east of Swift Run Gap, Virginia; in Frederick County, Maryland, and throughout its extent in Virginia, the Swift Run tuff occurs at a constant horizon at the contact of the Catoctin metabasalt and the injection complex; basal beds of the volcanic series contain pebbles of granitic rocks; the volcanic series is less metamorphosed than the injection complex; diabase dikes, genetically related to the metabasalt, cut the primary layering of the injection complex and show chilled borders.

Age of the Volcanic Series

The volcanic series, comprising the Catoctin basalt, aporhyolite, and the Swift Run tuff, overlies the granitic injection complex of early pre-Cambrian age. The volcanic series is unconformably overlain by the Lower Cambrian Loudoun formation. Diabase dikes, genetically related to the Catoctin metabasalt, intrude the injection complex but do not cut the Lower Cambrian rocks. In Frederick County and in southern Pennsylvania the unconformity at the base of the Loudoun formation is clearly shown by the fact that the Loudoun overlaps bands of aporhyolite and metabasalt, indicating that the volcanic rocks were somewhat folded and eroded before the Cambrian rocks were deposited. In the southern part of Frederick County the Loudoun formation overlaps the Catoctin metabasalt and Swift Run tuff and rests on the gneisses of the injection complex at the Potomac River (Fig. 5).

In Loudoun County, Virginia, south of Purcell Knob and farther southwest, the Loudoun formation directly overlies the Catoctin metabasalt. The average width of the outcrop of metabasalt south of Snickers Gap, Virginia, is 3 miles. At the gap the basalt is only 1 mile wide, and north of the gap its maximum width is 1½ miles. Hence at the gap and to the northward the Catoctin metabasalt appears to be thinner than in the area south of Snickers Gap. North of a point 8 miles north of the gap, in Purcell Knob and northeastward to Potomac River, the Loudoun formation overlaps the Catoctin metabasalt and Swift Run tuff and rests directly on granodiorite of the injection complex of early pre-Cambrian age. The writers believe that the thinning of the metabasalt at and north of Snickers Gap, and its absence in the area near Purcell Knob and in southern Frederick County, is the result of late pre-Cambrian uplift and erosion which occurred before the deposition of the Lower Cambrian Loudoun formation. The Swift Run tuff, the Catoctin metabasalt, and the aporhyolite are unconformable beneath the Lower Cambrian rocks and therefore are of pre-Cambrian age.

Since the volcanic series overlies the granitic injection complex, it is younger than that complex. Because it lacks the metamorphism, granitic intrusions and folding so pronounced in the injection complex, the Swift Run tuff, the Catoctin metabasalt, and the aporhyolite are regarded as of late pre-Cambrian age.

PALEOZOIC SEDIMENTARY ROCKS

GENERAL DESCRIPTION

Paleozoic rocks occur chiefly in Frederick County. They consist of quartzites, phyllites, and limestones of sedimentary origin. The quartzites and phyllites are the oldest and are of Lower Cambrian age. They are more resistant to erosion than the limestones and make hills and mountains. The limestones are of Cambrian and Ordovician age and form lowlands, chiefly Frederick Valley (Fig. 7, Columnar Section).

The quartzose rocks comprise the following formations, named in order of age and beginning with the oldest: Loudoun formation, Weverton quartzite, Harpers phyllite, and Antietam quartzite. The quartzose rocks are in two separate belts: (1) a mountainous tract which lies west of Frederick Valley and the Triassic upland, and (2) an eastern belt of low hills on the east side of the Frederick Valley and southeast of the Triassic upland. In the western belt the Cambrian quartzose rocks occur in two parallel north-trending ridges, Catoctin Mountain and South Mountain, both of which are synclinal in structure and lie on either side of the anticlinal Middletown Valley. The quartzose rocks, which formerly were continuous across the anticline, have been eroded, and the underlying pre-Cambrian rocks are now exposed in the Middletown Valley.

Catoctin and South Mountains are steep-sided wooded mountains. The rocks that compose them crop out chiefly along the rocky gorges of streams that cut into or through the mountains and in road cuts of graded roads. Near the north end of Catoctin Mountain the rocks are well exposed on State Highway 81 and on the Western Maryland Railroad, in the gorge of Owens Creek, but even here the individual beds that compose the formations are hard to trace, and the sequence and thickness of beds are hard to determine. Catoctin Mountain is breached also by Little Hunting Creek and Fishing Creek, and the quartzose rocks are well exposed in the gorges of these streams. U. S. Highway 40 crosses Catoctin Mountain at Braddock Heights, and South Mountain at Turners Gap. Both these gaps are low and the rocks are poorly exposed.

The rocky outcrops in the wooded gorges of Catoctin Mountain furnish attractive scenery and the streams are stocked with fish, so that these remote gorges are ideal

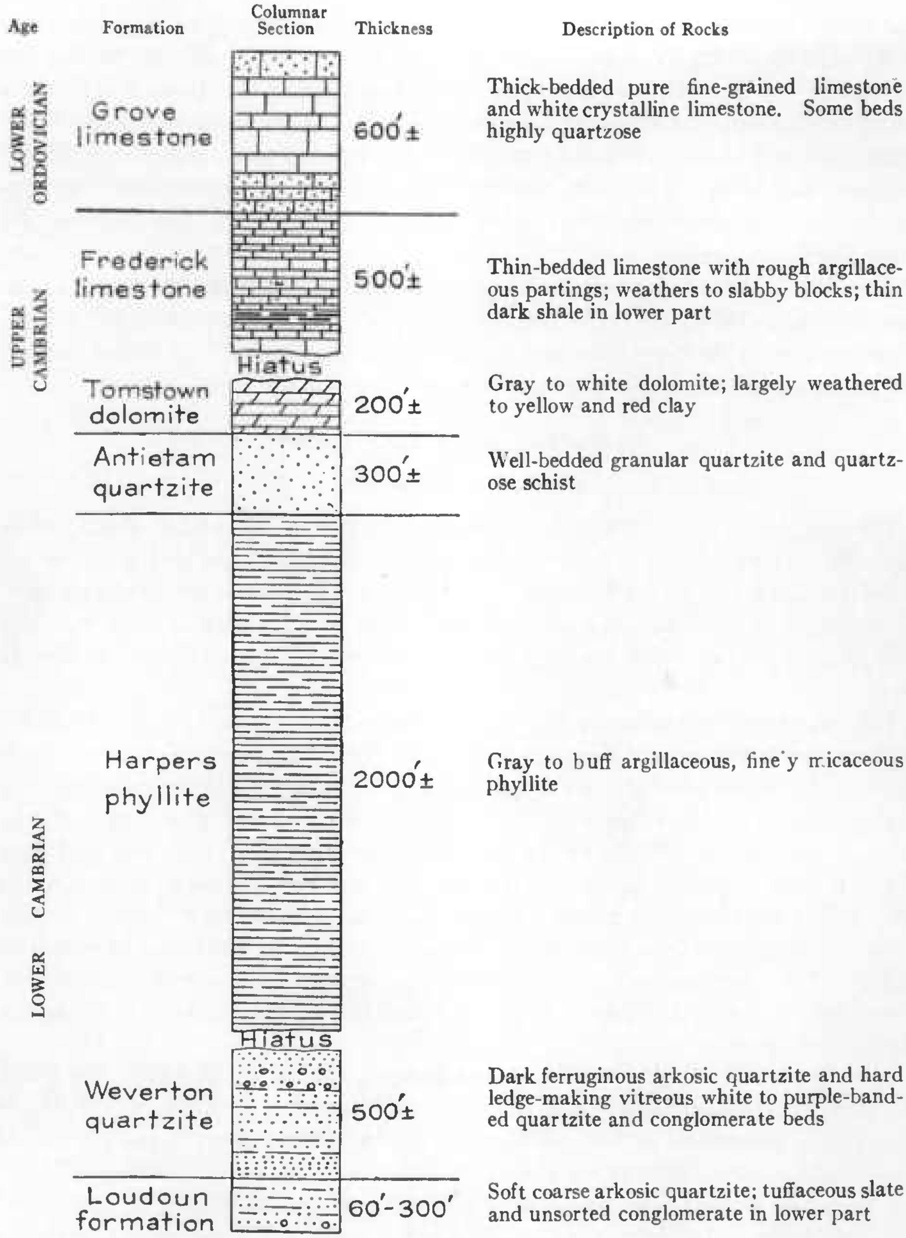

FIG. 7. Columnar section of the Paleozoic rocks

for recreation and outings. The city of Frederick gets its water supply from a reservoir above a dam on Fishing Creek (Pl. 19B) and paved roads in the valleys of the headwaters of this stream have made this attractive watershed accessible to motorists. Another recreation center northwest of Frederick is the near-by Gambrill

State Park around High Knob on Catoctin Mountain, where picnic grounds have been laid out and observation towers built, which furnish distant views of the Middletown Valley to the west and Frederick Valley to the east. At many points to the northeast on Catoctin Mountain, high ledges and cliffs of white quartzite rise above the wooded crests of the mountain and give extended vistas. These ledges include Wolf Rock, Chimney Rock, and White Rocks, which are accessible by mountain trails.

South Mountain is a single narrow wooded ridge not cut through by streams, and therefore it lacks clear exposures of the quartzose rocks. Outcrops on the road that crosses the mountain at Compton Gap are poor. The quartzose rocks are well exposed however on mountain roads on Lambs Knoll and on the west slope of the mountain on U. S. Highway 40 near Zittlestown, in Washington County. The Appalachian Trail follows the wooded crest of South Mountain from the Maryland-Pennsylvania State line to Potomac River.

Limestone has been extensively quarried for many years around Frederick. It forms the floor of Frederick Valley and crops out in many places. It is overlain by Triassic sedimentary rocks at the north end of the valley and in places along the west side. Limestone is also exposed in places on the west side of the belt of Triassic rocks, along the foot of Catoctin Mountain. In Frederick County the following limestone formations have been recognized: Tomstown dolomite of Lower Cambrian age, Frederick limestone of Upper Cambrian age, and Grove limestone of Ordovician age.

CAMBRIAN SYSTEM

Loudoun Formation

Distribution.—The Loudoun formation, the oldest of the Cambrian formations, occurs only in the western part of Frederick County where it crops out on the slopes and in places on top of Catoctin and South Mountains.

In Catoctin Mountain the Loudoun formation forms a wide belt on the west slope of the mountain from its northeast end, in Carrick Knob ridge, southwestward to High Knob. South of High Knob, as far south as U. S. Highway 340, it forms an eastern ridge of Catoctin Mountain, the main ridge to the west being composed of Catoctin metabasalt. South of that highway to Potomac River the Loudoun forms the crest of Catoctin Mountain except for a few miles in the vicinity of Pine Rock, where the overlying Weverton quartzite caps the mountain and makes its east slope. West of Point of Rocks the Loudoun formation in Catoctin Mountain is enclosed in a north-pitching syncline and is not present in the lower cliffs along the river (Fig. 20). North of High Knob the band of Loudoun formation on the west slope of the mountain widens and reaches the crest of the main ridge and in places extends down the east slope. Southeast of the broad flat saddle at Five Forks and in deep gaps in the main ridge north and south of Philips Delight School, tongues of the Loudoun extend a mile or more eastward down the gorges. East of Eyler's Valley, at the northeast end of Eagle Mountain, the Loudoun formation extends down a rocky gorge to the east foot of the mountain.

At the northeast end of Catoctin Mountain the Loudoun formation on the north slope of Carrick Knob ridge extends southward along the east slope of the ridge to Mount St. Marys, where it is cut off by the Triassic border fault. Southwest of Mount St. Marys the Loudoun is exposed at several places on the southeast slope of Catoctin Mountain. One long narrow area of the formation extends southwestward

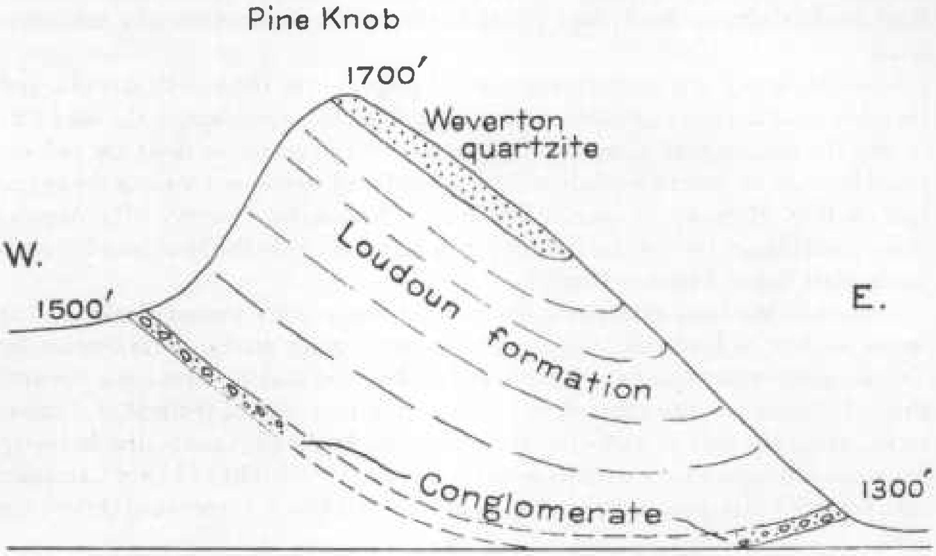

FIG. 8. Section of Pine Knob on South Mountain. Showing the Loudoun formation with basal conglomerate capped by Weverton quartzite.

to the gorge of Owens Creek, west of Roddy, and another long area lies south of Catoctin. The Loudoun also crops out in anticlines in some of the deeper gorges within the mountains, as on the headwaters of Fishing, Little Hunting, and Hunting Creeks.

In South Mountain the revised mapping of the Loudoun formation is shown in figure 5. The Loudoun forms a narrow belt on the lower east slope of the mountain from Potomac River northward to the east side of Lambs Knoll at Reno School. North of Reno School it is largely concealed by talus. North of Smoketown Gap it crops out on the south slope of Pine Knob, but is cut off on the east side of the knob by a local fault. Farther north a narrow band of the formation appears again on the east slope of South Mountain and extends to a point east of Cavetown, where the Loudoun passes northward into Washington County.

Small areas of quartzite which forms low hills south, southeast, and southwest of Everhart School on the U. S. Highway 40, $\frac{1}{2}$ mile southwest of Burkittsville, in the vicinity of Jefferson and 2 miles north of that town, are shown on the Frederick County map as Loudoun formation. As the writers have stated earlier in this report, later work in Frederick County and in the adjacent part of Virginia has proved that this quartzite is part of the Swift Run tuff, and is not of Cambrian age (Fig. 5).

Character and Thickness.—The Loudoun formation is largely a soft arkosic quartzite with beds of purer harder quartzite, quartzose conglomerate, and phyllite or slate. The lower beds of the formation are made up of residue from the disintegration of pre-

Cambrian granitic rocks on an old land surface, which lay to the east in Cambrian times. The residual waste was washed into a transgressing sea, in which it was deposited with little or no sorting. Some of the basal beds are red and green slate with scattered unassorted grains and small pebbles of quartz and feldspar, which appear to be little disturbed regolith. The character of these basal beds is best displayed at High Knob (Pl. 7A) and northward on the west slope of Catoctin Mountain to the vicinity of Carrick Knob, and at Pine Knob on South Mountain. On the west slope of Catoctin Mountain the basal beds contain bluish-gray and green tuffaceous slate which is overlain by a thin quartzite and coarse arkosic quartzite containing pebbles. Some of the tuffaceous slate is spotted with blue and green blebs. At High Knob these basal beds are 200 feet thick. At Pine Knob on South Mountain the arkosic quartzite is conglomeratic and has rounded pebbles of quartz and red jasper which range from 2 to 4 inches in diameter.

The upper beds of the Loudoun formation are a white to gray thin-bedded quartzite and purple banded arkosic quartzite, which shows current-bedding in places (Pl. 6B). The top of the formation is placed below the first prominent bed of purer vitreous quartzite of the Weverton. The Loudoun formation in Frederick County is variable in character and thickness. In South Mountain the thickness is about 200 feet. At Pine Knob north of Smoketown Gap, where the beds lie nearly horizontal in a syncline, the section of the Loudoun (Fig. 8) is:

Section of Loudoun Formation at Pine Knob on South Mountain

	feet
Hard dark vitreous quartzite (Weverton)	
Crumbly dark-banded feldspathic quartzite	100±
Purple-banded quartzite and thin white vitreous feldspathic quartzite, in part current-bedded	60±
Blue to purple shiny tuffaceous slate	20±
Thick coarse conglomerate of 2–4 inch rounded pebbles of quartz and red jasper, with interbedded shiny blue micaceous slate or phyllite	20±
	200±

In Catoctin Mountain the Loudoun formation is considerably thicker than in South Mountain. The characteristic slaty beds which form the lower part of the formation (Pl. 6A) are well exposed on the slopes of High Knob and along the steep west slope of Catoctin Mountain northward to the east end of the mountain. Above these slaty beds, which are about 200 feet thick, there are about 100 feet of soft dark-greenish pebbly arkose and slate, which are generally poorly exposed. These beds are included in the Loudoun because they lie beneath hard quartzites that are characteristic of the Weverton. The section of the Loudoun formation at High Knob is:

Section of Loudoun Formation ot High Knob on Catoctin Mountain

	feet
Hard dark quartzite, overlain by hard white quartzite (Weverton)	
Crumbly, schistose, white to gray quartzite with coarse grains of blue quartz and sericite partings	100±
Crinkled black slate, thin-bedded dark quartzite and pebbly arkose. Estimated	50±
Concealed; largely slate. Estimated	60±
Crinkled blue-green, shiny tuffaceous, blebby slate	100±
Greenstone (Catoctin metabasalt)	
	310±

The volcanic rocks which occur in the lower part of the Loudoun formation in Frederick County are bluish-gray tuffaceous slate. The underlying Catoctin metabasalt is a massive, green amygdaloid. Because no exposures of the contact of the blue tuff of the Loudoun with the underlying green metabasalt of the Catoctin have been found, their stratigraphic relation has not been observed, and it might be assumed that the blue tuff is part of the Catoctin metabasalt. In Loudoun County, Virginia, northeast of a point about 1 mile south of Purcell Knob, as has been mentioned earlier in this report, the Loudoun formation overlaps the Swift Run tuff and Catoctin metabasalt and rests directly on the granodiorite of the injection complex. In exposures on State Highway 9 at the south end of Purcell Knob, Virginia, blue tuffaceous slate beneath quartzite and arkose of the Loudoun formation rests directly on granodiorite on both limbs of the Purcell Knob syncline. In an anticline south of Stanley, Page County, Virginia, tuffaceous rocks at the base of the Loudoun similarly overlie granodiorite, and the Catoctin basalt is absent. It seems that the blue tuffaceous slate belongs in the Loudoun formation because it is present below quartzite and arkose of the Loudoun where Catoctin metabasalt is absent.

Age and Name.—The Loudoun formation in Frederick County extends across Potomac River into Loudoun County, Virginia, which is the type locality where the formation was named and first described by Keith.[30] The Loudoun formation contains no fossils, but it is comformably overlain by other quartzose formations, the uppermost of which, the Antietam quartzite, contains fossils of Lower Cambrian age. The Loudoun formation is therefore considered to be of Lower Cambrian age.

Weverton Quartzite

Distribution.—The Weverton quartzite overlies the Loudoun formation and is the main ridge-making formation of the Appalachian Mountains in Maryland. Catoctin and South Mountains and the Blue Ridge (Elk Ridge) are all composed chiefly of Weverton quartzite. In Catoctin Mountain, north of Braddock Heights, the Weverton caps Ridge Hill, High Knob ridge, and several intervening high ridge crests. Northwest of Yellow Springs it forms a wide belt of north-trending rugged ridges and rocky spurs that extend eastward from the crest of the main ridge to the east foot of the mountain. Southwest of Little Hunting Creek this belt of mountains has a maximum width of $2\frac{1}{2}$ miles, and northeast of that stream the belt narrows to $1\frac{1}{2}$ miles. North of Thurmont the main ridge trends northeast, and at Carrick Knob it trends east. South of Braddock Heights most of Catoctin Mountain is composed of Loudoun formation and the underlying Catoctin metabasalt. The Weverton quartzite is present on the crest and east slope of the mountain for a distance of only 2 miles in the vicinity of Pine Mountain.

In South Mountain the Weverton quartzite is well exposed in the Potomac River cliff, east of Weverton. Nearly the whole of this part of South Mountain is composed of Weverton quartzite. Hard quartzite in the upper part of the formation forms the crest and upper east slope from Potomac River to north of Crampton Gap (Fig. 5).

[30] Keith, Arthur, Harpers Ferry folio. U. S. Geol. Surv. Geol. Atlas No. 10, 1894.

This hard quartzite also caps Lambs Knoll. At Turners Gap, north of Lambs Knoll, the Weverton quartzite passes into Washington County, but again forms the crest of South Mountain in Frederick County from Monument Knob north to Smoketown Gap. North of this gap the crest of the mountain is offset to the east, where Pine Knob forms the crest and is capped by the Weverton. The Weverton quartzite

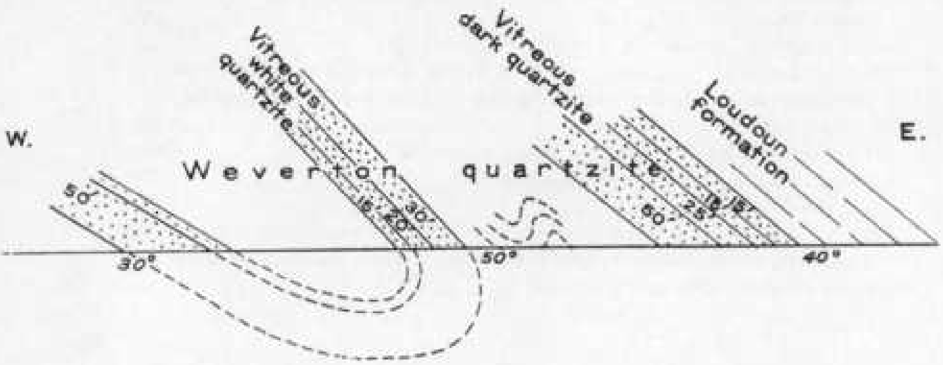

FIG. 9. Section of Weverton quartzite on State Highway 81 and W. M. R. R. on Owens Creek in Catoctin Mountain. Showing the upper white ridge-making quartzite enclosed in an overturned syncline.

forms the whole of South Mountain in the county for 5 miles north of Pine Knob, to the point where the county line swings sharply northeast. Here the Weverton formation extends into Washington County, and is not again exposed northward in Frederick County.

Character and Thickness.—The Weverton quartzite is composed largely of quartzites, some beds of which are massive, vitreous, and resistant, and make rocky ledges or ridge crests (Pls. 7–9). The best continuous exposure of the Weverton in Catoctin Mountain is along State Highway 81 and the Western Maryland Railroad, in the rocky gorge of Owens Creek through Eagle Mountain. Here, the ridge-making white quartzite in the upper part of the Weverton descends the south spur of Eagle Mountain in great white ledges to the stream and railroad at a point less than a mile southeast of Flint Station. A structure section of the rocks is shown in figure 9. The measured section is:

Section of Weverton Quartzite, Owens Creek Gorge

	feet
Soft gray quartzite with thin dark banding	30±
Thin-bedded white quartzite	15
Massive-bedded hard white quartzite (ledge maker)	50
Largely concealed; some purple banded white quartzite near top and some thin-bedded granular quartzite with dark glassy quartz grains and fine pebbles at the base. Estimated	250±
Dark granular quartzite with large clear and blue quartz grains, thicker bedded in middle, and a conglomerate with round quartz pebbles at base	105±
	450±

A composite section of the Weverton in Catoctin Mountain based on this measured section and other partial sections, is:

Composite Section of Weverton Quartzite, Catoctin Mountain

		feet
Soft quartzite with thin dark banding		50±
Thick-bedded white vitreous quartzite, some beds showing clear to bluish glassy quartz grains (chief ledge maker)	50±	260±
Softer quartzites, in part purple banded white quartzite	30±	
Thick-bedded white quartzite, containing grains of clear blue quartz and some feldspar and having sericite partings; thinner bedded and greenish in lower part	30	
Largely concealed; softer quartzite, poorly exposed	100±	
Granular, gray quartzite, somewhat feldspathic	20±	
Soft greenish sericitic quartzite	30±	
Dark ferruginous fine-grained quartzite with schistose partings and interbedded black slate, and at the base a bed of coarse, blue, vitreous quartzite and conglomerate of ½ inch rounded quartz pebbles		100±
		460±

The hard ledge-making quartzite at the top of the formation in Catoctin Mountain has been separately mapped to bring out the structure. This quartzite is a hard white vitreous rock 50 feet thick. It forms the top of most of the longitudinal ridges of the broader part of the mountain from High Knob north to Carrick Knob. The rocks are closely folded and many of these quartzite areas are crescent shaped because they are enclosed in tightly squeezed overturned synclines in which the east limbs are not clearly observable and may be faulted out. The white quartzite in some tightly squeezed synclines (Fig. 21) make conspicuous white ledges on the mountain tops, which are visible from the lowland to the east. The most prominent of these ledges are White Rocks northwest of Yellow Springs, Chimney Rock, Wolf Rock, and The Lookout west of Thurmont (Pls. 7B, 8, 9).

The spurs on the southeast slope of Roundtop and Carrick Knob, at the east end of Catoctin Mountain, are dip slopes of a plate of the cliff-making upper quarzite of the Weverton on the northwest limb of the Catoctin Mountain syncline. Wolf Rock (Pl. 7B) is a plate of the upper quartzite about 50 feet thick which dips 10° SE. at the south end. Northeastward the quartzite divides into two ledges, apparently forming the sides of an isoclinal syncline. Chimney Rock (Pl. 9) appears to be a nearly horizontal plate of the upper quartzite at the bottom of a similar syncline. The Lookout, west of Thurmont, seems to be an inclined plate of the upper quartzite on the west limb of a syncline. White Rocks (Pl. 8B), northwest of Yellow Springs, is a ledge of the upper quartzite, 20 feet thick, which dips 75° E., apparently on the west limb of a tightly closed syncline, the east limb of which is poorly exposed on the slope below. The Hamburg fire tower, on a spur of the mountain northwest of Yellow Springs and plainly visible from the Frederick Valley, is built on nearly horizontal beds of the upper quartzite (Pl. 8A). At the east edge of the top of the spur and on the steep slope below, the quartzite dips 70° SE., apparently forming the overturned east limb of a syncline.

The coarse dark ferruginous and conglomeratic quartzite at the base of the Weverton is well exposed $1\frac{1}{2}$ miles east of Flint Station, at the east entrance to the gorge of Owens Creek in Catoctin Mountain. Here the dark quartzite and conglomerate on the east limb of the overturned Catoctin Mountain syncline are exposed in fresh cuts along State Highway 81 (Fig. 9). These basal dark quartzites are 105 feet thick, and the massive white quartzite higher in the section is 50 feet thick.

In South Mountain the Weverton quartzite has a thick light-colored ledge-making quartzite at the top and hard dark-banded to white ledge-making quartzites at the base. The best exposure of the formation is in the cliffs above U. S. Highway 340 north of Potomac River, just east of Weverton (Pl. 10A), but a continuous section cannot be measured there. The softer beds are poorly exposed and the hard quartzites, which make rapids in the river (Pl. 10B), cannot be continuously traced in the cliffs north of the river. The structure and relations of the beds are not clear. Because of a repetition of a characteristic thick bed of hard conglomeratic quartzite and the synclinal structure of the rocks on South Mountain to the north, the structure in the cliff is interpreted as a closely compressed isoclinal syncline overturned to the northwest (Fig. 22). The section as thus interpreted is:

Section of Weverton Quartzite in South Mountain East of Weverton at Potomac River

		feet
Largely concealed; some dark ferruginous quartzite		50±
Thick-bedded, coarse to conglomeratic, hard light-gray quartzite, banded with purple (Upper ledge maker)		60
Largely concealed; some dark ferruginous quartzite	100±	270±
Hard white quartzite	40	
Largely concealed; some dark ferruginous quartzite	100±	
Softer thick-bedded quartzite	30±	
Thick- and thin-bedded granular quartzite (Lower ledge maker)		95
		475±

The Weverton quartzite is well exposed also in the cliffs north of Black Rock on the west slope of South Mountain in Washington County, where it lies nearly horizontal on the west limb of the South Mountain syncline. The measured section is:

Weverton Quartzite near Black Rock on South Mountain

			feet
Dark ferruginous coarse vitreous quartzite and gray pebbly quartzite with white and pink glassy quartz pebbles			20±
Dark vitreous quartzite	Upper ledge maker		100±
Thin conglomerate bed			
Gray quartzite with dark banding			
Conglomerate bed			
Slabby dark-greenish ferruginous quartzite containing red spots, magnetite crystals, and feldspar grains			250±
Shaly to slabby dark quartzite containing many magnetite crystals			
Dark purplish vitreous quartzite	25	Lower cliff maker	140
White and dark-purple banded vitreous quartzite with thin shale at top	65		
Dark vitreous quartzite	30		
Dark purple and white banded vitreous quartzite	20		
			510±

Slabby dark ferruginous quartzite containing some small pebbles (Loudoun)

On the east slope of South Mountain, where the beds are overturned on the east limb of the South Mountain syncline, the lower ledge-making beds of the formation are well exposed and the section is:

Partial Section of Weverton Quartzite, East Slope of South Mountain, West of Wolfville

			feet
Coarse granular dark vitreous quartzite containing dark glassy grains and ½ inch pebbles of quartz and magnetite crystals			20±
Largely covered; at top, gray fine-grained quartzite, containing magnetite crystals; lower part, thin-bedded fine, greenish quartzite containing magnetite crystals			150±
Thick-bedded coarse granular quartzite containing black shale pebbles	40	Lower ledge maker	180
Thick-bedded white vitreous quartzite	60		
Concealed	20		
Gray vitreous quartzite, current-bedded, laminated, and banded with dark streaks	20		
Well-bedded, thick-bedded gray vitreous quartzite containing grains of glassy quartz	40		
			350±
Pebbly schistose quartzite and slate (Loudoun)			

From these sections it is seen that the Weverton quartzite in South Mountain is made up of two ledge-making hard quartzites separated by softer beds, and that the generalized section is:

Generalized Section of Weverton Quartzite, South Mountain

	feet
Dark- to light-gray quartzite with conglomerate beds (Upper ledge maker)	100±
Shaly to slabby dark ferruginous quartzite containing glistening quartz grains and magnetite crystals	250±
White quartzite and dark-purple banded quartzite (Lower ledge maker)	150±
	500±

The lower ledge-making quartzite, which is well exposed in a quarry at Weverton on Potomac River, is believed to be the same as that which makes the cliffs at Black Rock and Calico Rock northwest of Pine Knob. The upper ledge-making conglomeratic quartzite, which makes the top of the cliff at the river east of Weverton and caps the ridge to the north, is believed to be the same as the conglomeratic quartzite which caps South Mountain north of Pine Knob. This upper quartzite is not present in the syncline at the road in Crampton Gap, but it forms the crest of the ridge north and south of the gap.

The variation in thickness and character of the Weverton quartzite and of the underlying Loudoun formation across the strike is shown in figure 10.

Age and Name.—The Weverton quartzite was named from Weverton on Potomac River, where the formation is well exposed. No fossils have been found in the formation, but it is conformably overlain by the Harpers phyllite and Antietam quartzite and is considered to be of the same age as those formations. The Antietam quartzite contains fossils of Lower Cambrian age.

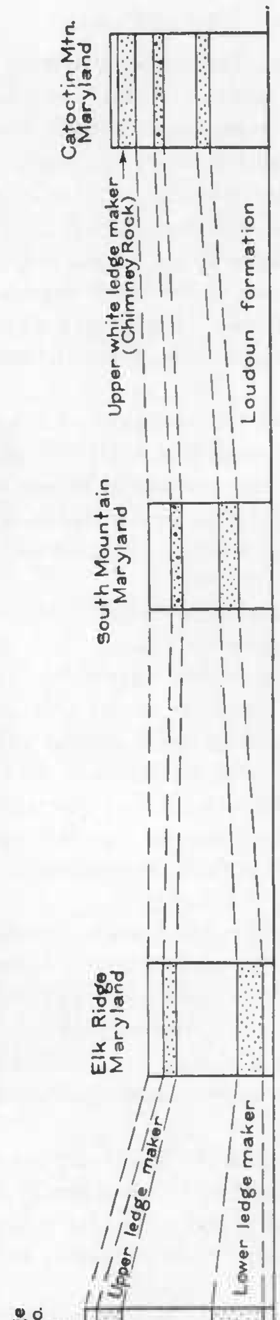

FIG. 10. Sections of Loudoun formation and Weverton quartzite showing variation in character and thickness across the strike.

Harpers Phyllite

Distribution.—The Harpers phyllite normally overlies the Weverton quartzite, but in Frederick County it occurs chiefly in a belt of foothills on the east side of Catoctin Mountain where it occupies a narrow fault block between the Triassic border fault on the east and a nearly parallel fault on the west. The base of the Harpers is everywhere faulted out in Frederick County, so that it does not rest on the Weverton quartzite. From a point west of Indian Springs to Potomac River, the Harpers in the narrow fault block is overlain by the Antietam quartzite. The belt of Harpers phyllite is nearly a mile wide east of Braddock Heights and tapers to nothing at a point 1 mile north of Point of Rocks. It also narrows northward to less than $\frac{1}{4}$ mile west of Mountaindale, but widens again where the bounding faults diverge north of Catoctin.

Harpers phyllite is present on the west slope of South Mountain in Washington County, west of Fox's Gap. A small area of Harpers phyllite about $\frac{1}{2}$ mile wide and 2 miles long occurs also in the hills east of the Triassic upland, at the north edge of Carroll County. The Harpers phyllite here underlies Antietam quartzite, and these two formations lie between the Martic overthrust on the southeast and the overlapping Triassic rocks on the northwest.

Character and Thickness.—The Harpers phyllite in Frederick County is in general a buff-gray phyllite or finely micaceous slate. It is bluish gray when fresh, but weathers readily to buff color and to slaty fragments. It is very uniform in character and has few distinctive beds. However, in the area east of the Triassic upland in northern Carroll County, a quartzite bed is present and has been mapped near the base of the Harpers. In the vicinity of Thurmont the Harpers is mapped as unconformably overlain by Frederick limestone, but quartzose beds at places adjacent to the limestone may be part of the overlying Antietam quartzite. If such is the case, the Frederick limestone near Thurmont unconformably overlies the Antietam, as it does in the eastern part of Frederick Valley.

The Harpers phyllite south of Braddock is a fine-grained green chlorite schist with muscovite flakes. It is closely folded, and quartz layers are drawn out into lenses. In thin section of the phyllite, muscovite is seen to contain quartz inclusions. Garnets are in clusters in chloritic layers, and magnetite occurs in the quartzose layers. Magnetite occurs also in Harpers phyllite in exposures near and northeast of Braddock. The chlorite-muscovite schist grades northward and southward along the strike into typical phyllite.

The full thickness of the Harpers phyllite is not present in Frederick County because the lower part of the formation, which normally rests on Weverton quartzite, is not exposed. Its upper limit is defined by the quartzose beds of the Antietam. Its total thickness in adjacent parts of Pennsylvania and Virginia is estimated to be about 2000 feet.

Age and Name.—Keith[31] named the formation the Harpers shale from Harpers Ferry, West Virginia, on Potomac River, 4 miles west of Frederick County. The Harpers at the type locality is a fine-grained slaty phyllite similar to the Harpers

[31] Keith, Arthur, op. cit., U. S. Geol. Surv. Geol. Atlas No. 10, 1894.

phyllite of Frederick County. No fossils have been found in the Harpers phyllite, but it is considered to be of Lower Cambrian age because it is conformably overlain by the Antietam quartzite which contains Lower Cambrian fossils.

Antietam Quartzite

Distribution.—The Antietam quartzite occurs in the foothills on the east side of Catoctin Mountain west of the Frederick Valley, and in a series of linear hills in the eastern part of the valley. A small area of Antietam quartzite lies east of the Triassic upland in northern Carroll County. In the foothills of Catoctin Mountain it crops out in a narrow belt about $\frac{1}{4}$ mile wide which extends from Point of Rocks at Potomac River to Little Tuscarora Creek northwest of Frederick, where it is cut out by the Triassic border fault. The quartzite throughout this belt is underlain by Harpers phyllite and is overlain by Tomstown dolomite, in normal sequence. North of Thurmont, along the same strike, poorly exposed quartzose schist and thin quartzite, on which the Frederick limestone rests, making low hills in the area mapped as Harpers phyllite, possibly should have been mapped as Antietam quartzite overlying the Harpers. The Antietam quartzite is not present in South Mountain in Frederick County but is well exposed at the west foot of the mountain in Washington County south and east of Smoketown.

On the east side of the Frederick Valley the Antietam quartzite forms a discontinuous line of low wooded hills from New Midway, where the quartzite is overlapped by Triassic sedimentary rocks, southwestward to Potomac River. These low hills rise abruptly out of the limestone valley. The quartzite here is unconformably overlain by the Frederick limestone of Upper Cambrian age. Both the quartzite and the limestone are bounded on the east side by the Martic overthrust. At the north end of this belt the Antietam quartzite forms two lines of hills. Laurel Hill, which is an anticlinal ridge west of the main belt, lies out in the limestone valley and its south end terminates at Cabbage Run. Other short anticlinal ridges in the valley begin at U. S. Highway 40, east of Frederick, and extend southwestward. The highest and most prominent of these quartzite ridges begins southwest of Frederick Junction and extends to Potomac River. Here the outcrops of Antietam quartzite are nearly 2 miles wide. The quartzite is well exposed in road cuts on U. S. Highways 40 and 240 and in outcrops on Monocacy River southeast of Frederick, where the river cuts through the formation at several places. The small body of Antietam quartzite at the north edge of Carroll County, east of the Triassic upland, overlies Harpers phyllite and is overlapped by the Triassic rocks.

Character and Thickness.—The Antietam quartzite west of Frederick Valley is a well-bedded light-gray, rusty-weathering, granular, quartzite and underlying crumbly, sericitic quartz schist. The best exposures of the formation are along roads southwest of Feagaville, on U. S. Highway 40 at Braddock, and in the low ridge at Fuller. The prominent part of the formation is a thin-bedded, fine-grained, rusty-weathering quartzite about 20 feet thick. The uppermost beds of the Antietam are laminated calcareous quartzite which splits readily along the bedding planes, the surfaces of which are stained by rust-colored iron oxide and contain molds of fossils. The lower part of the formation is a crumbly sericitic quartz schist, generally poorly exposed so that the base of the formation is indefinite. In Washington County the Antietam quartzite contains *Scolithus* tubes, but none were observed in Frederick County. The total thickness of the Antietam quartzite in the belt west of Frederick Valley is estimated to be about 300 feet.

The Antietam quartzite in the eastern part of Frederick Valley is largely quartz schist with beds of thin-bedded tough gray quartzite with rust specks. Its thickness cannot be determined because it crops out in anticlines and the base of the formation is not exposed. Cleavage is so strongly developed in these rocks that bedding can seldom be observed. Because of the unconformity at the base of the overlying Frederick limestone, the upper fossiliferous beds of the Antietam may not be everywhere present. From the uppermost ferruginous quartzite beds exposed near Monocacy River, 2 miles southeast of Frederick, the writers collected poorly preserved trilobite spines.

Age and Name.—The Antietam quartzite is named from Antietam Creek, Washington County. It is well exposed in that county in Short Hill, west of South Mountain, and in the higher foothills west of Elk Ridge. Casts of fossils have been found in the uppermost beds of the formation in the foothills of Catoctin Mountain, 2 miles east of Jefferson, as well as at the locality on Monocacy River mentioned above. The fossils collected were fragments of unidentifiable trilobites and shells similar to those collected in the Antietam in nearby parts of Maryland and Pennsylvania, which have been identified as *Camarella minor*, *Hyolithus communis*, *Obolella* sp., and fragments of *Olenellus* sp. These fossils are of Lower Cambrian age.

Tomstown Dolomite

Distribution and Character.—A narrow belt of Tomstown dolomite extends along the east foot of Catoctin Mountain west and southwest of Frederick. The dolomite lies between the ridge of Antietam quartzite and the Triassic border fault. The dolomite crops out at few places. At a point 1½ miles north of Point of Rocks, and also 1½ miles southwest of Feagaville, white crystalline dolomite overlies the topmost rusty beds of the Antietam quartzite. Elsewhere in this belt, as far north as Braddock, the dolomite is weathered to red clay and is further concealed by wash from the adjacent mountain slope. In Rock Creek valley, north of Braddock, the presence of a kiln and pits in the lowland adjacent to the topmost rusty beds of the Antietam indicate a former outcrop of dolomite. Near Shookstown hard gray knotty dolomite of the Tomstown crops out in the fields, and to the west calcareous rusty-weathering quartzite of the Antietam is exposed dipping east under the dolomite. The belt of Tomstown dolomite is cut off on the east by the Triassic border fault, so that its full thickness is not exposed. Its thickness in this area is about 200 feet.

East of Point of Rocks, dark carbonaceous clay with fragments of shale and plicated calcareous mica schist containing small tourmaline crystals, which are found in the old iron ore pits in the lowland east of the ridge of Antietam quartzite, indicate the presence of dolomite or limestone, which is believed to be the southward continuation of the belt of Tomstown dolomite exposed to the north.

Tomstown dolomite is not present above the Antietam quartzite elsewhere in Frederick County. In Washington County, west of South Mountain, it is well exposed and overlies the Antietam quartzite.

Age and Name.—The Tomstown dolomite is named from the village of Tomstown, Pennsylvania, near Chambersburg, where it overlies the Antietam quartzite of South Mountain. The dolomite that lies above the Antietam quartzite in Frederick County, and the red residual clay derived from it, have the characteristics and stratigraphic position of the basal beds of the Tomstown dolomite. No fossils have been found in it in Pennsylvania, but the Waynesboro formation, which conformably overlies it in the Chambersburg region, contains Lower Cambrian fossils, so it is of Lower Cambrian age. The Shady dolomite, equivalent to the Tomstown in southern Virginia and the region to the southwest, also contains fossils of Lower Cambrian age.

Frederick Limestone

Distribution.—The Frederick limestone is a thin-bedded slabby blue limestone which forms the floor of most of the Frederick Valley. In the vicinity of Frederick the limestone area is over 5 miles wide, and its length, from New Midway to the Potomac River, is nearly 25 miles. Thick-bedded pure Grove limestone overlies the Frederick limestone in the center of the valley and in several narrow areas northwest of Frederick. A narrow belt of Frederick limestone is present between low anticlinal ridges of Antietam quartzite along the east side of the Frederick Valley east and southeast of Woodsboro, east of Frederick, and along Monocacy River west and southwest of Hopeland. An inlier of the formation occurs east of the hills of Antietam quartzite at the south end of the county, north of the mouth of Monocacy River. The Frederick limestone is exposed also east of the foothills of Catoctin Mountain in a narrow belt 5 miles long, north of Catoctin, and in a smaller area south of Mount St. Marys. A small area of Frederick limestone west of Thurmont, and a larger area to the north extending from Roddy to Mount St. Marys, lie within the foothills.

Character and Thickness.—The Frederick limestone in general is a dark-blue limestone in thin layers, 1 to 3 inches thick, separated by thin dark irregular argillaceous partings. Some thin beds of the limestone are granular and coarsely crystalline. Freshly quarried blue limestone appears massive and dark blue, but on exposure to the weather it breaks into slabby layers with uneven bedding surfaces. These slabs are much used in building stone fences, walls, and foundations. On weathering, the argillaceous partings are left in the soil as dark shaly fragments.

No continuous section of the Frederick limestone is exposed, but the general sequence and estimated thickness of beds based on scattered outcrops in Frederick Valley are:

Generalized Section of Frederick Limestone in Frederick Valley

	feet
Grove limestone:	
Thick-bedded limestone containing numerous scattered grains of glassy quartz.	
Frederick limestone:	
Thin slabby dark-blue limestone containing a 20 foot bed of thick-bedded pure, finely laminated limestone	50±
Slabby thin-bedded argillaceous blue limestone and thin granular coarsely crystalline gray limestone with numerous thin dark argillaceous partings; some beds fossiliferous. Estimated	200±

	feet
Smooth-layered slabby and shaly banded argillaceous limestone; weathers to shaly soil. Estimated	100±
Black to gray shale	50±
Buff earthy limestone; weathers to buff tripoli and porous earthy sandstone	15±
Blue mottled and irregularly banded argillaceous limestone, which weathers to buff earthy reticulated network, and lenticular pure limestone in argillaceous matrix, which weathers to a knotty, spotted, conglomeratic-looking rock	40±
Banded argillaceous limestone, weathers white	10±
Concealed	15±
	480±

The gray to black shale near the base of the Frederick limestone makes a narrow band traceable nearly continuously along the east side of the limestone valley from

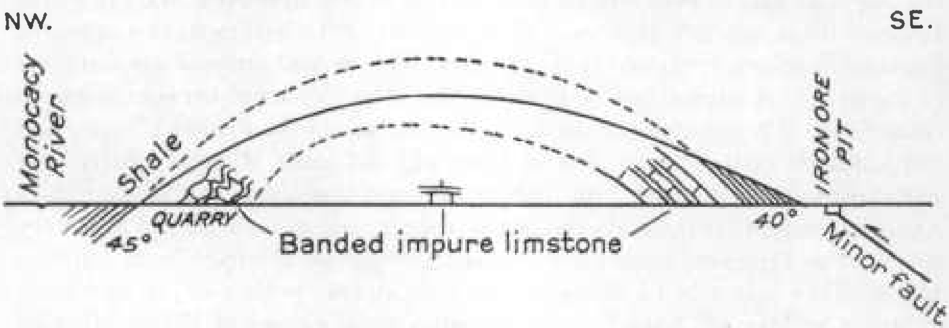

FIG. 11. Sketch section of lower beds of the Frederick limestone on U. S. Highway 40, southeast of Frederick Junction. Shows shale underlain by buff earthy-weathering impure-banded limestone in an anticline.

Frederick Junction to beyond Walkersville, and has been mapped. It is spangled with mica and in places contains pyrite, small tourmaline crystals, and small round concretions. The shale is best exposed north of Monocacy River in the railroad cut at Frederick Junction and in its vicinity. In the railroad cut, black fissile shale is associated with thin-bedded to shaly earthy-weathered limestone. In exposures on U. S. Highway 240 (Fig. 11), south of the river, banded black shale, about 50 feet thick, is underlain by quartzose limestone, which weathers to a buff porous sandstone, and impure reticulated blue limestone. The reticulated limestone, which is exposed in a small roadside quarry, resembles a limestone conglomerate in argillaceous matrix. The smooth-layered slabby limestone exposed in the western and northern parts of the Frederick Valley has not yielded fossils. The argillaceous banded limestone, which is generally fossiliferous, occurs in the upper part of the formation and crops out east and southeast of Frederick near the quarries in the overlying Grove limestone.

In a small quarry adjacent to the old Grove quarry (also called Tabler quarry), near the railroad, 1 mile southeast of Frederick, the section of the uppermost beds of the Frederick limestone is:

Upper Beds of Frederick Limestone, 1 Mile Southeast of Frederick

	feet
Platy dark-blue limestone with smooth even parting planes marked by trails and raindrop impressions	15
Thick-bedded dark-blue, finely laminated pure limestone	20
Mottled thick-bedded limestone, weathered pitted and looks like a reef	10±
Thin platy dark-blue limestone with very irregular bedding surfaces due to wavy argillaceous partings	5±

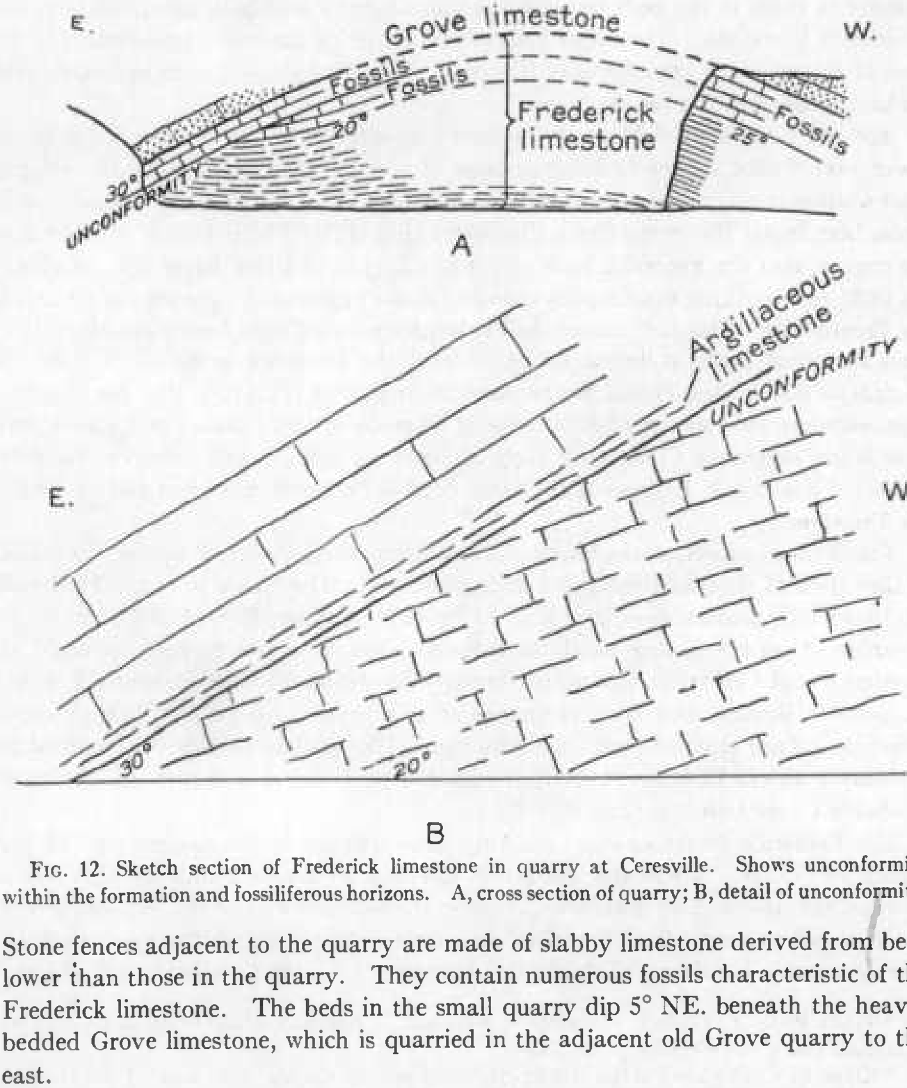

FIG. 12. Sketch section of Frederick limestone in quarry at Ceresville. Shows unconformity within the formation and fossiliferous horizons. A, cross section of quarry; B, detail of unconformity.

Stone fences adjacent to the quarry are made of slabby limestone derived from beds lower than those in the quarry. They contain numerous fossils characteristic of the Frederick limestone. The beds in the small quarry dip 5° NE. beneath the heavy-bedded Grove limestone, which is quarried in the adjacent old Grove quarry to the east.

In the limestone quarry at Ceresville, on Monocacy River, the upper part of the Frederick limestone, exposed in an anticline, is overlain by the Grove limestone (Fig. 12). The Frederick limestone there exposed is thick-bedded dark limestone (3 foot beds) interbedded with thin-bedded gray limestone rhythmically banded by dark argillaceous partings which weather to earthy shale fragments. The bedding surfaces of the weathered out thin limestone slabs have deeply pitted surfaces coated with thin black carbonaceous films. On the west wall of the quarry, these beds are unconformably overlain (Fig. 12) by 20 feet of thick-bedded light-blue limestone with wavy buff partings. At the base of these unconformable beds there is an earthy-weathering argillaceous limestone which weathers to a reticulated silicious network. Although the unconformity is very marked, fossils in the upper beds are similar to those in the beds beneath the unconformity and both groups of beds are Frederick limestone. The upper beds of the Frederick limestone are overlain by 12 feet of thick-bedded granular gray limestone containing glassy quartz grains, typical of basal beds of the Grove limestone.

Age and Correlation.—Most of the fossils collected from the Frederick limestone have been found on the bedding-surfaces of weathered slabs in stone fences east and southeast of Frederick, near outcrops of these fossiliferous beds. Some fossils have been found also in the Ceresville quarry (Fig. 12). Philip Tyson[32] was the first to suggest that the Frederick limestone is of Chazyan or Black River age. Keyes,[33] in 1890, reported that brachiopods collected in the Frederick Valley were of Chazyan or Trenton age. Bassler[34] named the Frederick limestone from Frederick, Maryland, and identified fossils collected by Stose from the Frederick limestone in 1909 as *Acidaspis ulrichi* Bassler and *Strophomena stosei* Bassler (Pl. 11, A, B). He reported also undetermined species of *Reteocrinus*, *Cameroceras*, and *Isotelus*, and stated that this fauna suggests a Chazyan or early Mohawkian age. A well-preserved trilobite collected later by A. I. Jonas at the south edge of Frederick was identified by Ulrich as *Triarthus* sp.

The writers subsequently found that the structural evidence in the Frederick Valley did not support this faunal interpretation.[35] The fossils from the Frederick and Grove limestones were later studied by G. A. Cooper, E. O. Ulrich, and A. F. Foerste. Cooper[36] distinguished the following species of brachiopods collected at Frederick and Ceresville: *Zenorthis* (formerly *Strophomena*) *stosei* Bassler (Pl. 11A), *Z. jonasae* Bassler, and another species of this genus. Cooper states that these brachiopods are of late Upper Cambrian age. The trilobite previously identified as *Acidaspis ulrichi* Bassler (Pl. 11B) is regarded by Ulrich and Raymond as also of probable Upper Cambrian age.

The Frederick limestone rests on Antietam quartzite in the eastern part of the Frederick Valley. There the Tomstown dolomite of Lower Cambrian age, which overlies the Antietam in normal sequence in the foothills west of the Triassic border fault, is not present. The Frederick limestone of Upper Cambrian age, therefore, unconformably overlaps the Antietam quartzite of Lower Cambrian age. In the

[32] Tyson, Philip T., Geologic formations of Maryland. State Agricultural Chemist, 1st Rept. to Maryland House of Delegates, p. 35, 1860.

[33] Keyes, C. R., Discovery of fossils in limestone of Frederick County, Maryland. Johns Hopkins Circ., vol. 10, p. 32, 1890.

[34] Bassler, Ray, Cambrian and Ordovician. Md. Geol. Surv., p. 115 and 117, 1919.

[35] Jonas, A. I., and Stose, G. W., Age reclassification of the Frederick Valley (Maryland) limestones. Geol. Soc. Amer. Bull., vol. 47, pp. 1658–1671, 1936.

[36] Personal communication; also Ulrich, E. O., and Cooper, G. A., New genera and species of Ozarkian and Canadian brachiopods. Jour. Pal., vol. 10, No. 7, pp. 616–631, 1936.

center of the Frederick Valley syncline the Frederick is overlain by the Grove limestone of Ordovician age.

ORDOVICIAN SYSTEM

Grove Limestone

Distribution.—The Grove limestone was named by the writers[37] from Grove Station. It is a thick-bedded pure limestone which is quarried for lime at many places in the Frederick Valley. In the middle of the valley it forms a belt about a mile wide which extends from a point south of Buckeystown northward to LeGore, where it is overlapped diagonally by the Triassic sedimentary rocks. The belt widens north of Fountain Rock, and at its north end, west of Woodsboro, it attains a width of 2 miles. Several narrower bands of the formation lie to the west of the main belt, and extend from the south end of Chestnut Hill southwestward to U. S. Highway 40, west of Frederick.

Character and Thickness.—The Grove limestone is a thick-bedded high-calcium limestone, with beds of massive dolomite in the lower part and highly quartzose limestone at the base. The most complete section of the Grove limestone is a composite section from the LeGore quarry (Fig. 13), which is:

Grove Limestone, LeGore Quarry

	feet
North wall of quarry:	
Chalky white to dove-colored, fine-grained limestone and marble; upper beds contain scattered quartz grains; one brachiopod found	80±
Fine-grained dark-blue limestone, some scattered quartz grains in lower beds; contains cephalopods	30±
South wall of quarry:	
Thick-bedded dark- to light-dove, pure fine-grained limestone containing crystalline specks, small crinoid stems and basal plates, and brachiopods. Estimated	150±
Thick-bedded fine-grained pure limestone	100±
Thin-bedded platy to shaly dark argillaceous limestone, with dark graphitic to buff argillaceous partings. At base, dark limestone banded with buff argillaceous laminae, apparently filling narrow irregular crevices and solution channels in underlying granular limestone	50±
Pure fine-grained gray limestone, some beds finely laminated and shaly, with dark carbonaceous partings. Thin lenticular dolomite near top; thick-bedded, fine-grained, pure, dove-colored limestone at base	60±
Thick-bedded limestone and glistening dolomite, some layers full of rounded grains of glassy quartz, probably in part wind blown, and showing current-bedding. Estimated	100±
Banded blue limestone and thin layers of granular limestone with scattered grains of glassy quartz	20±
	590±
Thin-bedded banded argillaceous blue limestone (Frederick limestone)	

The limestone in the Barrick quarry, west of the railroad at LeGore, is assumed to be the west limb of an isoclinal syncline of which the limestone in the LeGore quarry is the east limb. The section in the Barrick quarry is:

[37] Stose, G. W., and Jonas, A. I., Limestones of the Frederick Valley, Maryland. Wash. Acad. Sci. Jour., vol. 25, pp. 564–565, 1935.

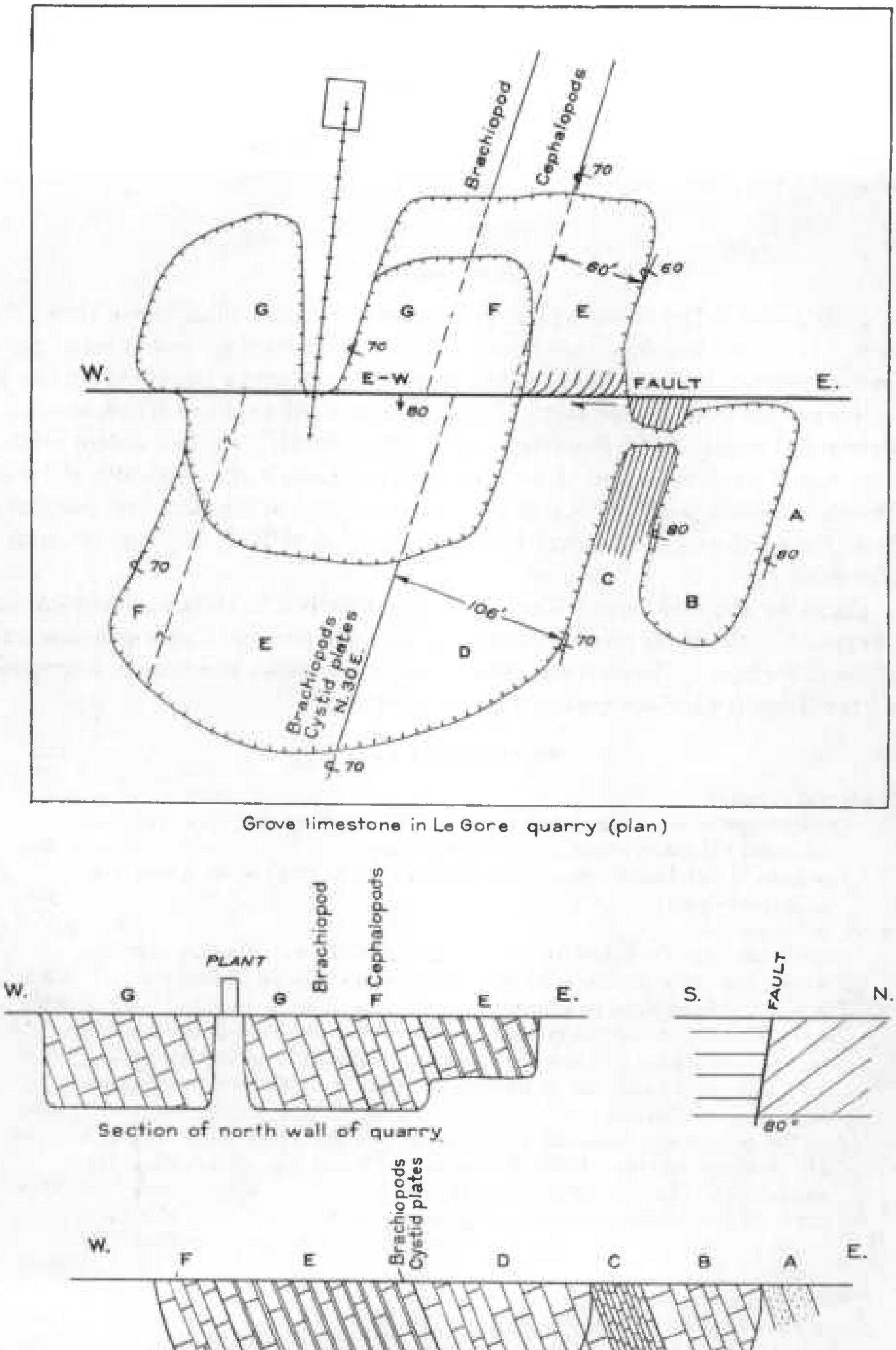

FIG. 13. Map and sections of Grove limestone in LeGore quarry. Rocks in quarry offset on nearly vertical east-west fault. Showing divisions of the Grove limestone:

North wall: (G) White to dove-colored limestone; one brachiopod. (F) Dark dove-colored pure limestone; cephalopods.

South wall: (E) Light and dark dove-colored pure limestone, dark argillaceous partings; brachiopods and cystid plates. (D) Dark dove-colored pure limestone. (C) Thin-bedded slabby argillaceous limestone. (B) Pure, blue to dove-colored limestone. (A) Granular limestone full of rounded quartz grains.

Partial Section of Grove Limestone, Barrick Quarry

	feet
Dark impure limestone (east wall)	
Thick-bedded dove to dark-gray finely laminated pure limestone with stylolites and some scattered quartz grains. Estimated	130±
Thick-bedded light-dove to white finely laminated pure limestone	50±
Thick-bedded dove to dark fine-grained pure limestone	50±
Lenticular dolomite beds in pure limestone	10
Thick-bedded pure dark laminated limestone; weathers white	20±
Fine-grain, even-grain white marble	5
Hackly to shaly black argillaceous limestone with black carbonaceous partings; some beds weather to buff earthy blocky fragments (west wall)	20±

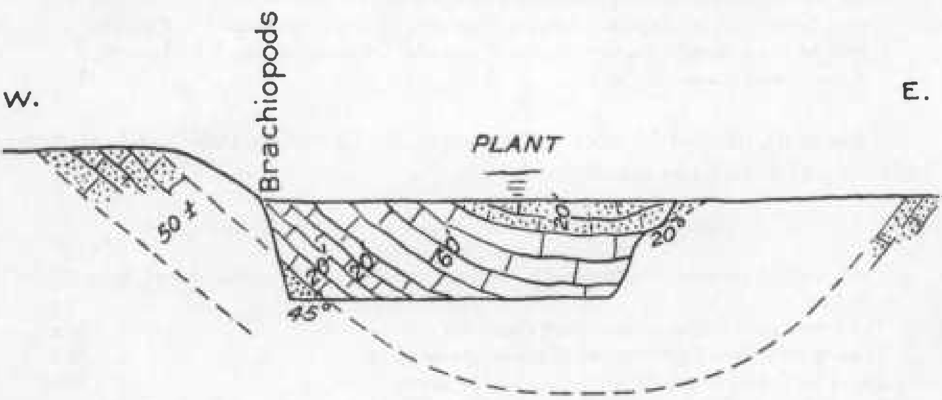

FIG. 14. Sketch section of Grove limestone in Grove quarry. Shows beds of quartzose limestone containing round grains of glossy quartz, and 100′ ± of pure limestone.

The section of the Grove limestone at the Grove quarry (Fig. 14), south of Grove Station on the Frederick branch of the B. &. O. railroad, is:

Grove Limestone in Grove Quarry

	feet
Thick-bedded limestone containing quartz grains and weathering to a porous sandstone	20
Dense blue limestone, with scattered quartz grains near the top	60±
Dark- and light-gray, fine-grained limestone weathering chalky. Contains fossils	20±
Dense dark-gray, fine-grained pure limestone, containing scattered quartz grains and with fine wavy argillaceous partings	20±
Massive-bedded dark limestone with wavy argillaceous banding and numerous quartz grains; weathers to current bedded porous sandstone	50±

The basal beds of the Grove limestone are invariably quartzose, due to the presence of scattered round grains of glossy quartz which stand out in relief on the weathered surface of the rock. In places the quartz grains are so numerous that the rock weathers to a porous sandstone, and residual sand from its disintegration is dug for building sand. The sand collects in deep depressions between pinnacles of undissolved siliceous limestone. The quartzose beds have been separately mapped as an aid in the structural interpretation and as a guide to possible deposits of residual sand for building purposes. In the northern part of the Frederick Valley the limestone is so quartzose that it makes a low ridge, which extends south for 2½ miles from the west end of Chestnut Ridge, and a lower ridge which lies just to the west. The basal quartzose beds are conglomeratic in places, containing limestone pebbles up to 3–4 inches long. In a small quarry on Tuscarora Creek, ½ mile southeast of Bloomfield, the following section of siliceous limestone conglomerate is exposed:

Quartzose Limestone in Grove Limestone, 1 Mile Southeast of Bloomfield

	feet
Thick-bedded quartzose gray granular limestone with a few scattered limestone pebbles	10
Thin-bedded banded siliceous limestone with a few limestone pebbles	10
Coarse conglomerate composed of slabby fragments 1½ inches thick and 3 to 4 inches long of fine-grained limestone in coarse granular limestone matrix full of coarse glassy quartz grains	20±

On the south bank of Monocacy River, opposite Ceresville, these basal quartzose beds are well exposed as follows:

Quartzose Limestone in Grove Limestone, South of Ceresville

	feet
Thick-bedded granular limestone with scattered grains of glassy quartz, 5-foot bed at base	50±
Thick dark pure limestone with fossil fragments	20±
Thick massive blue limestone full of glassy quartz grains	30±
Thinly laminated limestone with glassy quartz grains	30±
Thin-bedded argillaceous blue limestone, thicker bedded below, with dark argillaceous partings (Frederick limestone)	

Age.—The Grove limestone was considered by Bassler[38] to be of Beekmantown age on the basis of cephalopods found at the LeGore quarry. He believed that these thick-bedded limestones were overlain by the thin-bedded Frederick limestone of supposed Chazy age. In 1926, Jonas found that a massive quartzose limestone and dolomite was always present at the contact of the massive-bedded limestone with the Frederick limestone. In 1933–34, Stose and Jonas found that the much quarried massive pure limestone in the center of the Frederick Valley lies in a syncline in the Frederick limestone and does not underlie it.

Cephalopods collected in 1914 by Bassler, Ulrich, and Stose in a cavern in the Grove limestone in the north wall of the LeGore quarry were identified by Ulrich and Foerste[39] as *Ectenolites* (new species), *Levisoceras* sp., *Walcottoceras* (new genus), and *Cameroceras* sp. In 1935 a single specimen of *Clarkoceras* was found with the above listed cephalopods. Ulrich and Foerste correlate these beds with the Chepultepec of the southern Appalachians and the Gasconade of Missouri, of lowermost Ordovician age (Upper Ozarkian of Ulrich). Brachiopods collected from the Grove limestone in the Grove and LeGore quarries have been identified by G. A. Cooper[40]

[38] R. S. Bassler, op. cit., pp. 114–115.

[39] Ulrich, E. O., and Foerste, A. F., New genera of Ozarkian and Canadian cephalopods. Denison Univ. Bull., Jour. Sci. Lab., vol. 30, pp. 267–272, 278, 289, 1935.

[40] Ulrich, E. O., and Cooper, G. A., op. cit., pp. 616–631.

as five new genera: *Apheoörthis*, *Nanorthis*, *Glyptotrophia*, *Clarkella*, and *Syntrophina*. Cooper states that this fauna also indicates lower Ordovician age (Upper Ozarkian of Ulrich). A few gastropods collected in the Grove quarry were identified by Bridge as *Sinnopea* sp., which is also found in the Chepultepec of the Appalachians. The Grove limestone is therefore of Lower Ordovician age.

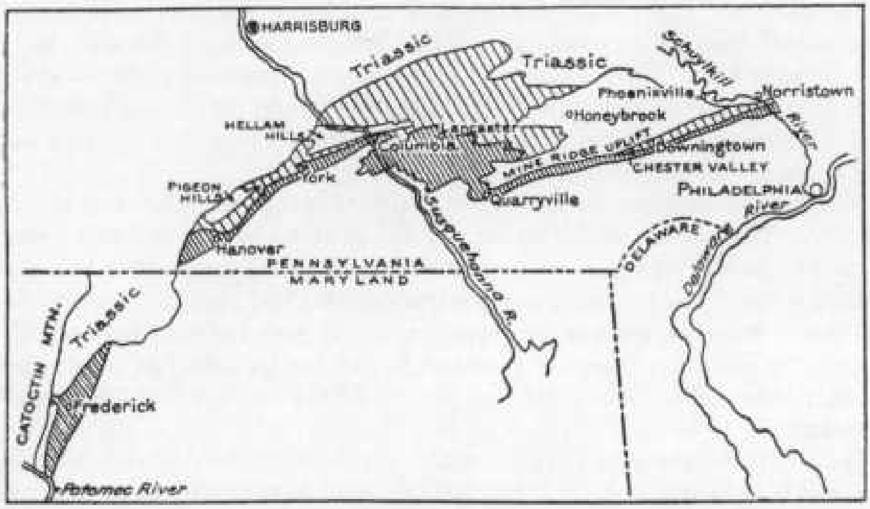

FIG. 15. Map showing geographic relation of the Frederick and Grove limestones (densely-ruled pattern) of Frederick County to partly equivalent Conestoga limestone (densely-ruled pattern) in the Hanover-York-Lancaster valleys of Pennsylvania. Open-ruled pattern, other Paleozoic limestones.

As fossils are not plentiful in the Grove limestone, the localities where fossils have been collected are described. The largest number were collected in the LeGore quarry (Fig. 13). Cephalopods were found chiefly in the north wall of the quarry, where a few brachiopods also were obtained. Five genera of brachiopods, a trilobite, and cystid plates are numerous in the south wall. In the Grove quarry (Fig. 14) three genera of brachiopods and a small cephalopod were collected. Gastropods were found in the old Grove quarry, $\frac{1}{4}$ mile south of the present active Grove quarry.

Correlation.—Eighteen miles northeast of the Frederick Valley, in the Hanover Valley, Pennsylvania, and extending northeastward into the York and Lancaster Valleys, the Conestoga limestone unconformably overlies limestones and shales of Lower Cambrian age (Fig. 15). The Conestoga limestone is largely a thin-bedded blue limestone with argillaceous partings, which lithologically resembles the Frederick limestone. Near the base of the Conestoga in Hanover Valley is thick-bedded granular limestone containing scattered grains of glassy quartz and pebbles of limestone, similar to the basal beds of the Grove limestone. These quartzose beds of the Conestoga limestone also weather to porous sandstone, and the residual quartz sand is dug for building sand. No fossils have been found in the Conestoga limestone in the Hanover, York, and Lancaster Valleys, but the Conestoga has been traced eastward into the Chester Valley where fossils collected from it have been identified by Ulrich and Foerste to be of Upper Canadian (Beekmantown) age. The Frederick and Grove limestones, therefore, are believed to be equivalent in part to the Conestoga limestone in the Hanover and Lancaster Valleys.[41]

CRYSTALLINE ROCKS OF THE PIEDMONT UPLAND

Baltimore Gneiss

The Baltimore gneiss is the oldest rock in the Piedmont upland. The formation was named[42] from the excellent outcrops in Baltimore City along the banks of Jones and Gwynns Falls. The rock at the type locality is a granitoid gneiss occurring in beds from an inch to 6 feet in thickness, traceable in places for 100 feet in the quarry face. Light-colored feldspathic beds alternate with very thin black layers of highly biotitic or hornblendic material.

Baltimore gneiss is exposed only in one small area in the southeast corner of Carroll County. The area is bounded on the east and south by North and South Branches of the Patapsco River which join at the southeast corner of the county a mile east of Marriottsville. The Baltimore gneiss extends a mile along the strike between North and South Branches, and the best exposures are in gorges of both branches of the river. The northwest boundary is formed by the Setters formation which overlies the Baltimore gneiss. This gneiss area is in the northwestern part of the Woodstock anticline.

The Baltimore gneiss in Carroll County is a distinctly banded rock with black bands rich in biotite which contrast strongly with light-colored layers of granitic appearance. It contains also layers of hornblende gneiss. The rock is closely folded and the dip of the layers is from 30° to 40° NW.

The banded gneiss is made up of white to pinkish feldspar and rounded or lenticular grains of clear grayish or white quartz and flakes of black biotite. The feldspar is both microcline, a potash feldspar, and oligoclase, a soda-lime feldspar. The rock is thoroughly crystalloblastic; it was formed in a deep zone and the interlocking areas of quartz and feldspar were crystallized at the same time. On the border of the microcline there is developed myrmekite, a characteristic constituent of the Baltimore gneiss. Myrmekite is a micro-intergrowth of vermicular quartz in plagioclase, probably formed by replacement of potash of the microcline by lime and soda; during the process, silica was liberated. Biotite is present in variable amount and is deep greenish brown to straw yellow in color, usually arranged in bands. Characteristic accessory minerals are titanite, garnet, zircon, and apatite.

A pink augen-gneiss which occurs near Marriottsville, Howard County, probably represents the Hartley augen-gneiss which intrudes the Baltimore gneiss in some places in Baltimore County, notably in the Glenarm and Texas anticlines. It is a biotite-rich rock with blades of biotite wrapped around lenticular areas of quartz and feldspar. These areas in cross section resemble eyes, hence the name augen-gneiss. The feldspars are microcline and oligoclase, with associated myrmekite.

The origin of the Baltimore gneiss and its chemical composition at the type locality were discussed in detail in the Maryland Geological Survey's report on Balti-

[41] Jonas, Anna I., and Stose, Geo. W., op. cit. Geol. Soc. Amer. Bull., vol. 47, pp. 1657–1674, 1936.

[42] Williams, G. H., Geology of Baltimore and its vicinity. Extract from Guide Book of Baltimore for Am. Inst. Min. Eng., pp. 77–124, 1892.

more County. It was concluded from the appearance of the formation in the field, that the massive granitoid gneiss exposed in the City of Baltimore probably represents a sedimentary formation. Study of microscopic section of the rock furnishes evidence in support of this conclusion. Recrystallization in a deep zone has been so complete, however, that a sedimentary origin cannot be proved. Elsewhere in Baltimore County the Baltimore gneiss is an injection gneiss containing dark-colored biotitic layers that represent remnants of original sediment, and may show fraying out at the ends of the bands due to resorption action of the invading magma. The injection gneiss has ptygmatic folds that are highly complex primary folds developed during the injection of the igneous material into a softened schist. The injection gneiss in the Phoenix anticline in Baltimore County is so distinctly banded that it may be called a ribbon gneiss. The granitic layers pinch and swell in the biotitic bands. In places the contortion is so great that the axes of the folds stand in a vertical position. The Baltimore gneiss contains pegmatites which are recrystallized alaskitic rocks that have undergone intense metamorphism. The Hartley augen gneiss is an intrusive body that recrystallized under stress and movement in a deep zone. The granitoid gneiss at the type locality and the injection gneisses, hornblende gneiss, altered aplite, and Hartley augen gneiss are mapped in Baltimore County as the Baltimore gneiss. The term Baltimore gneiss as it has been applied, therefore, refers to an igneous complex which resembles the injection complex exposed in the core of the Middletown anticline in Frederick County and in adjoining parts of the Blue Ridge uplift in Virginia. The Baltimore gneiss, like the injection complex of the Blue Ridge uplift, is regarded as of early pre-Cambrian age.

The Baltimore gneiss, or the injection complex as it should be called, is exposed in Maryland only in the Woodstock and adjoining anticlines in the southeastern part of the crystalline schist area, but it undoubtedly underlies all of the crystalline schist area at shallow depth. The injection complex exposed in these anticlines is only a small part of similar rocks which are covered by the Setters formation, Cockeysville marble, and Wissahickon formation in synclines between the uplifts. This conclusion is evident from the facts that different types of the injection complex crop out in the several uplifts and the types show no regular arrangement in the different uplifts, and all the rock types are overlapped on their borders by the overlying formations. In the southeastern part of the area of crystalline schists, the injection gneiss thus is the core of the closely folded envelope composed of Setters quartzite, Cockeysville marble, and crystalline schists. North of this major anticlinal uplift the crystalline schists form a closely folded belt, 20 to 25 miles wide. The Baltimore gneiss must underlie the schists at depth, for in Pennsylvania it forms the core of the Mine Ridge anticline which plunges southwest and passes under the crystalline schists.

EASTERN SEQUENCE OF CRYSTALLINE SCHISTS

Setters Formation

The Setters formation[43] received its name from Setters Ridge, which forms the north front of the Chattolanee anticline, Baltimore County. The Setters formation

[43] Williams, G. H., Structure of the Piedmont Plateau. Geol. Soc. Amer. Bull., vol. 2, p. 308, 1891.

directly overlies the Baltimore gneiss and forms a ridge on the northwest side of the Woodstock anticline. The outcrops in Carroll County are poor and the section is better exposed on the Howard County side of the Patapsco River from Marriottsville eastward, along cuts of the Baltimore and Ohio Railroad and southward to the old Frederick Road. The Setters formation dips 25°–45° NW. and rests on the Baltimore gneiss with an obscured contact in this area. At the Carroll-Baltimore County line in the vicinity of North Branch of Patapsco River, the Setters formation is in a close fold in which the beds are overturned to the southeast. The formation comprises three lithologic types: mica schist, vitreous quartzite, and mica gneiss. The base of the formation in Carroll County, as elsewhere in Maryland, is a feldspathic mica schist. It is overlain by muscovite quartzite, followed by mica schist and mica gneiss which are poorly exposed in Carroll County. Although the actual contact of the Setters formation and Baltimore gneiss east of Marriottsville is not visible, the strike of the lowest observable beds of the Setters is discordant to that of the nearest exposure of Baltimore gneiss 30 feet to the east. This divergence in structure combined with the more pronounced folding in the Baltimore gneiss are evidences of the unconformity between them. Structural discordance between the two formations was observed at contacts exposed on Piny Creek on the north side of the Phoenix anticline in Baltimore County. There, the divergence in average strike of the two formations is 20°; the Baltimore gneiss is more closely folded and deformed than the Setters formation and is intruded by the Hartley augen gneiss, which does not penetrate the Setters formation.

The mica schist is a fine- to medium-grained schist composed of quartz, feldspar, and biotite, which spangles the rock. The quartzite is a coarse-grained, vitreous rock speckled with pale-pink kaolinized feldspar, and contains silvery flakes of muscovite developed along bedding planes. The rock is sometimes stained pinkish red due to oxidation of magnetite. Black tourmaline, which is characteristic of all beds of the Setters formation, is especially abundant in the quartzite. Tourmaline crystals occur on the bedding planes of the quartzite and the crystals are commonly broken and "stretched" as a result of dynamic disturbance. In thin section the quartzite is seen to be made up chiefly of interlocking areas of quartz and microcline, straw-colored blades of muscovite, scanty magnetite, and rounded zircon.

The mica-gneiss of the Setters is a dark-gray to black fine-grained gneiss composed of biotite, quartz, and feldspar. In places biotite is in coarse black porphyroblastic blades which give the rock a spotted appearance. The biotitic variety is usually more quartzose and less feldspathic than typical biotite gneiss. In thin section the mica gneiss, which is thoroughly crystalloblastic, is made up of microcline, abundant biotite, and quartz. An analysis of this member of the Setters formation is published in the Maryland Geological Survey's Report on Baltimore County[44] from a specimen taken on the north side of the Glenarm anticline. The rock is high in potash, perhaps because the highly potassic Hartley augen gneiss, or a similar rock, furnished much of the detrital material which composes the Setters formation.

The maximum thickness of the Setters formation, measured on the north side

[44] Knopf, E. B., Jonas, A. I., Geology of the Crystalline rocks of Baltimore County. Md. Geol. Surv., p. 157, 1929.

of the Glenarm-Towson anticline in Baltimore County, is 1100 feet. The Setters is very variable in thickness and, on the flanks of the Phoenix anticline in Baltimore County, is absent in several places. On the borders of the Woodstock anticline its maximum thickness is estimated at 250 feet.

Cockeysville Marble

The Cockeysville marble is named from the small town of Cockeysville, 10 miles north of Baltimore. On the geologic map of Carroll County all the marble and limestone exposed in the crystalline rocks of the Piedmont upland are mapped as Cockeysville, but the name Cockeysville is now restricted to the narrow band of marble overlying the Setters formation in the southeast corner of Carroll County. The marble in northeastern Carroll County is now mapped as Wakefield marble (Fig. 4); and in the western part of Carroll County and the eastern part of Frederick County, where marble is associated with volcanic rocks, the albite-chlorite schist facies of the Wissahickon formation, and the Marburg schist, it is mapped as Wakefield marble and Silver Run limestone on the Frederick County geologic map. They will be described with the rocks of the western sequence.

The Cockeysville marble overlies the Setters formation on the flanks of anticlinal arches in Baltimore County, where it forms valleys between the ridges of the Setters formation and hills underlain by the Wissahickon formation. It enters the southeast corner of Carroll County from Baltimore County, where it parallels the west and north sides of the Setters formation in the Woodstock anticline, and forms a narrow valley which extends southwestward into Howard County at Marriottsville. It was formerly quarried and the rock was burned for lime at quarries south of North Branch of the Patapsco River and north of South Branch.

The Cockeysville marble is a completely crystalline white marble of variable grain, ranging from fine-grained to a coarse sugary texture. It is dolomitic in part and contains bronzy mica, usually concentrated in layers, accessory feldspar and quartz, and such metamorphic minerals as tremolite and diopside. Pressure effects are shown in the polysynthetic twinning of the calcite, gridiron structure of the microcline, and strain shadows in the quartz. Analyses of the Cockeysville marble are given in the report on Baltimore County.[45]

The thickness of the Cockeysville marble cannot be measured because of the lack of exposures. In Minebank Valley, Baltimore County, the thickness was estimated to be 400 feet.

Muscovite pegmatite intrudes the Cockeysville marble at its contact with the overlying Wissahickon formation. The pegmatite enters Carroll County from Baltimore County, crosses the county and passes southwestward into Howard County.

Wissahickon Formation

The Wissahickon formation was named from Wissahickon Creek,[46] a tributary to the Schuylkill River near Philadelphia, Pennsylvania. The Wissahickon forma-

[45] Idem., p. 165.

[46] Bascom, Florence, Md. Geol. Surv. Cecil County Report, p. 104, 1902.

tion has two mineralogical facies. One facies, called the oligoclase-mica schist, lies southeast of the Peters Creek formation; the other, called the albite-chlorite schist facies, lies northwest of the Peters Creek formation. The latter facies will be described with the rocks of the Western sequence.

Oligoclase-Mica Schist Facies.—The oligoclase-mica schist facies occurs only in a small area in the southeastern part of Carroll County, but is exposed over a large area in Baltimore County. It is characterized by a strong intensity of metamorphism and is similar to the Wissahickon mica gneiss of the type locality in Pennsylvania. In Carroll County the oligoclase-mica schist occurs above the Cockeysville marble on the west limb of the Woodstock anticline. It underlies rolling hilly country with good outcrops along Patapsco River and its tributaries. The soil derived from the mica schist is a deep clay, sparkling brilliantly with abundant flakes of mica.

The oligoclase-mica schist facies is a succession of mica schist and mica gneiss interbedded with thin layers of impure quartzite. The mica schist beds are finely plicated, and are coarse to medium grained. Biotite, muscovite, and quartz are dominant constituents, associated with a variable content of oligoclase. The mica occurs in large blades that spangle the cleavage surfaces and wrap around lenticular areas of quartz or around large pink garnets, which are usually abundant. The gneissic layers consist chiefly of quartz, biotite, oligoclase ($Ab_{70}An_{30}$), and less abundant orthoclase. Coarse-grained layers, in which quartz predominates, alternate with fine-grained bands made up of biotite, plagioclase, and small interlocking grains of interstitial quartz. Characteristic accessory minerals are garnet, apatite, zircon, and magnetite. The quartzite layers are composed chiefly of recrystallized quartz, fine-grained biotite, and a small amount of microcline feldspar. It contains the same accessory minerals as the mica gneiss.

The oligoclase-mica schist shows by its complete recrystallization, its coarse micas, and its content in Baltimore County of such minerals as garnet, staurolite, and kyanite, that the crystalline condition has been developed by metamorphic agencies at high temperature and under directed pressure. The aluminous silicates, staurolite and kyanite, are minerals characteristic of metamorphism at high temperature. The Wissahickon oligoclase-mica schist, like the underlying Setters formation and Cockeysville marble, is closely folded, with recumbent folds, and no estimate of thickness can be made.

Peters Creek Formation

The Peters Creek formation was named[47] from its typical exposures along Peters Creek, which flows into the Susquehanna River at Peach Bottom, Lancaster County, Pa. It has been traced along the strike from Pennsylvania across Baltimore County, Maryland, into Carroll County, where it underlies a belt 2 to 4 miles wide in the southeastern part of the county. Its northwestern boundary at the Baltimore County line is at Emory Church and extends S. 60° W. to South Branch of Patapsco River at a point west of Hoods Mills. On the northwest side the Peters Creek formation grades into the albite-chlorite schist facies of the Wissahickon, and the

[47] Knopf, E. B., Jonas, A. I., Stratigraphy of the crystalline schists of Pennsylvania and Maryland. Am. Jour. Sci., vol. 5, p. 46, 1923.

boundary between these two formations has therefore been represented on the Carroll County map by a dashed line. The Peters Creek formation lies northwest of the oligoclase-mica schist facies of the Wissahickon formation on the northwest limb of the Woodstock anticline. In Carroll County an intrusive body of serpentine lies at the contact of these two formations.

The best exposures of the Peters Creek formation occur along North Branch of Patapsco River south of Beaver Run, on Morgan Run near the Beaseman Road where a quarry was opened for road material, and on the Baltimore and Ohio Railroad west of Hoods Mills. The formation consists of a series of biotite-chlorite-muscovite-quartz schist, interbedded with biotite-chlorite quartzite containing garnet. It is a medium- to fine-grained, lustrous, grayish-green schist and quartzite containing biotite, chlorite, epidote, muscovite, oligoclase, and albite, with accessory garnet, magnetite, zircon, and apatite. East of Eldersburg it contains large garnets with alteration rims of chlorite. Chlorite also fills cracks and surrounds relict cores of garnet. Biotite also is altered to chlorite. The chloritization of garnet and mica is a retrogressive change which has altered minerals of high-rank metamorphism to minerals of lower rank metamorphism. The zone of retrogression extends northeastward into and across Baltimore County. The quartzose beds have the same constituents as the schist, with a greater proportion of quartz. Quartzite is not so well developed in the Peters Creek formation in Carroll County as in the Susquehanna region[48] where the formation was named and where blue quartz grains are a prominent constituent.

Analyses of the Peters Creek formation in Lancaster County, Pennsylvania, have been given in a previous report.[49] Because of close folding and development of cleavage, no estimate of the thickness of the formation can be made.

The Peters Creek formation occupies a syncline in which the foliation dips northwest on the northwest side of the Woodstock anticline and southeastward in the region west of Eldersburg. This syncline extends northeast across Baltimore and Harford Counties, Maryland, and into Pennsylvania, where it was named the Peach Bottom syncline because it contains there infolded Cardiff conglomerate and Peach Bottom slate. The Cardiff conglomerate and Peach Bottom slate are regarded by the writers[50] as probably of Ordovician age.

WESTERN SEQUENCE OF CRYSTALLINE SCHISTS

General Statement.—The sequence of the crystalline schists that lie northwest of the Peters Creek formation differs from the sequence east of that formation. In southeastern Carroll County the oligoclase-mica schist facies of the Wissahickon formation dips northwest under the Peters Creek formation, which is enclosed in the Peach Bottom syncline. Northwest of the syncline the Wissahickon formation is of a different metamorphic facies, the albite-chlorite schist facies. The albite-

[48] Knopf, E. B., Jonas, A. I., Idem, pp. 36–37.

[49] Geology of the McCalls Ferry-Quarryville District, Pennsylvania. U. S. Geol. Surv., Bull. 799, p. 37, 1929.

[50] Stose, G. W., and Jonas, A. I., Geology and Mineral Resources of York County, Pennsylvania, Penn. Geol. Surv., 4th series, Bull. C.67, p. 106, 1939.

chlorite schist and the partially equivalent Marburg schist are underlain by a thick series of volcanic flows and tuffaceous slates of basic and acidic composition.

The volcanic series comprises the Sams Creek metabasalt, Libertytown metarhyolite, Ijamsville phyllite, and Urbana phyllite. The volcanic series is interbedded with and overlain by quartzites. The Sugarloaf Mountain quartzite overlies the Urbana phyllite. Quartzites occur also in the albite-chlorite schist of the Wissahickon and the Marburg schist. The volcanic rocks overlie the Wakefield marble. The Marburg schist overlies the Silver Run limestone, which may be equivalent to the Wakefield marble.

The Wakefield marble, Silver Run limestone, some of the formations of the volcanic series, and the Marburg schist were named by the writers[51] and were mapped on the geologic map of Frederick County. The metabasalt of the Frederick County map is here named the Sams Creek metabasalt from a village of that name on the Carroll-Frederick County line, and the metarhyolite is here named the Libertytown metarhyolite from Libertytown, Frederick County.

When the geologic map of Carroll County was published in 1928, the Wakefield marble was thought to be equivalent to the Cockeysville marble and was so named on the geologic map. Because of lithologic resemblance to the Conestoga limestone, the Silver Run limestone was tentatively regarded as Conestoga. The quartzites infolded with the Marburg schist in the vicinity of Wentz, were placed provisionally in the Lower Cambrian, and the adjoining part of the formation now called Marburg schist was called Harpers phyllite. Later work in Pennsylvania and in Carroll and Frederick Counties, Maryland, has caused the writers to revise the earlier tentative interpretation. Their later views are expressed on the geologic map of Frederick County, which includes the western part of Carroll County, and in figure 4 of this report.

Wakefield Marble

The Wakefield marble is associated with volcanic rocks, and the marble and volcanic rocks underlie the albite-chlorite schist facies of the Wissahickon formation. The Cockeysville marble overlies the Setters formation on the flanks of anticlines exposing Baltimore gneiss, and does not have volcanic rocks associated with it. Because of these differences in association, the name Wakefield has been applied to the marble that underlies the volcanic rocks in Carroll and Frederick Counties.

The Wakefield marble and the associated volcanic rocks extend from the Maryland-Pennsylvania State line in eastern Carroll County southwestward through Westminster, and pass westward into Frederick County, where they form a belt over 10 miles wide east of the Frederick Valley. Triassic sedimentary rocks cover the marble and volcanic rocks on their north side from a point 2 miles north of Union Bridge westward to the vicinity of New Midway. In the area west of Shrivers Mill to Linwood and extending south to Sams Creek, and in the area south of Union Bridge, the marble occurs in several narrow parallel curving bands in the metabasalt, and the repetition of curving bands appears to be stratigraphic and the marble and meta-

[51] Jonas, A. I., and Stose, G. W., New formation names used on the geologic map of Frederick County, Maryland. Jour. Wash. Acad. Sci., vol. 28, no. 8, p. 346, 1938.

basalt seem to be interbedded. However, the marble apparently does not merge into the metabasalt or interfinger with it. The repetition of curving bands may be the result of folding of previously formed isoclinal anticlines exposing narrow bands of underlying Wakefield marble.

Wakefield marble exposed in two narrow areas in the eastern part of Carroll County is directly overlain by the albite-chlorite schist facies of the Wissahickon formation. The northern of these two areas extends from Gunpowder Falls southwestward up a small tributary valley to Millers. The marble is poorly exposed, but where it crops out on the west side of the valley it dips 15° NW. under the albite-chlorite schist. Three miles south of Millers, the marble again crops out for a distance of $3\frac{1}{2}$ miles in the valley of East Branch of Patapsco River. The best exposures in this area are in the vicinity of Hoffman's Mill, where marble underlies quartzite which lies at the base of the Wissahickon formation. The marble, quartzite, and schist strike N. 30° E. and dip 15° NW. The outcrops near the mill show that the marble is in the core of a recumbent anticline that pitches gently southwest, and the marble passes beneath the Wissahickon formation at a point $\frac{1}{2}$ mile south of the mill. In these two eastern exposures of the marble, no volcanic rocks are present between the Wakefield marble and the Wissahickon schist. It is assumed that this belt lies southeast of the eastern edge of the volcanic flows and tuffs.

The western belt of Wakefield marble begins at the north edge of Carroll County in the vicinity of Lineboro and extends southwestward in several narrow discontinuous bands, in a belt $2\frac{1}{2}$ miles wide, for a distance of 18 miles to Warfieldsburg. The marble has a linear outcrop which trends S. 35° W. It crops out in several parallel areas that pass through Melrose, Ebbvale, and Bixler, on the northwest side of Dug Hill Ridge, and along a narrow belt that lies on the southeast side of that ridge, northwest of Manchester. Marble crops out also near Westminster, Spring Mill, and southwestward to a point 2 miles northeast of Taylorsville. In this linear belt, volcanic rocks commonly overlie the marble. Where the albite-chlorite schist of the Wissahickon formation overlies the marble in this belt, the absence of volcanic rocks is probably due to faulting.

In the region west and southwest of this linear belt, the Wakefield marble has a curvilinear strike which is common to the associated rocks in that area. There the Wakefield marble is repeated several times across the strike and is interbedded or infolded with the volcanic rocks. From a point near Shrivers Mill, the marble trends south and then curves northwest and west. This curving strike is repeated in a fourfold series of curves. The southward curving belt of marble between Shrivers Mill and Wakefield Mill is 3 miles long; that between New Windsor and Linwood is 6 miles long. In the third curving belt the marble trends south from the neighborhood of Union Bridge for a distance of 14 miles to a point 1 mile northeast of New Market. In the southwestern part of this belt, southwest of Unionville, the outcrops of marble are discontinuous and irregular in trend. At the southwest end of this curving belt the marble trends west and then curves north and northeast again. The western curving belt of marble passes through Libertytown and extends southwest to a point 2 miles northwest of New Market. The northwest side of this marble belt passes through Centerville and ends 1 mile northwest of that place, at a southwest-trending normal fault. Southwest of Libertytown, in the vicinity of New London and at the southwest end of the curving belt, the marble outcrops are not continuous.

The sharply curving strike of the marble is made evident by the presence of alternating parallel bands of marble and volcanic rocks and by the topographic pattern produced by the differential resistance to solution and erosion of these two types of rock. The series of parallel curving valleys and hills produced by erosion is especially well shown on the topographic map between Shrivers Mill and Union Bridge and between New Windsor and Weldon. The curvilinear strike is due to the fact that the fold axes are steeply inclined. Where the pitch of the fold is gentle, the outcrop of the marble at the end of the fold is wide. This is well shown by the wide expanse of marble in the Wakefield Valley, Priestland Valley, and in the valley west of Union Bridge. At the ends of steeply pitching folds, the outcrops are not so wide. On the limbs of the folds, where the marble is greatly thinned by intense compression, the outcrops are commonly narrow and the marble is squeezed out in places. The marble occupies valleys. The expo ures are not continuous because of deep solution and soil cover (Pl. 11C). On the map of Frederick County marble is mapped where it crops out, and its probable continuation along the strike in valleys between exposures is indicated by a dashed black line. Marble may be present but not exposed in these strike valleys, or it may have been squeezed out into lenses during intense compression, so that it now occurs in discontinuous areas.

An isolated inlier of marble and Sams Creek metabasalt in the Marburg schist is exposed southeast of Ridgeville, Carroll County. In the cut of the Baltimore and Ohio Railroad, just east of the tunnel through Parrs Ridge, green marble is exposed in an anticline beneath green albite schist and interbedded blue slate, which are mapped as metabasalt. The marble is exposed for a distance of 20 feet in the railroad cut and cannot be traced along the strike. Both the marble and blue slate contain pyrite, which weathers to red iron oxide specks.

In the region northeast of Bachman Mills, the marble has weathered to a white or blue clay and rarely crops out. In the vicinity of Ebbvale and northeast of Melrose, where deposits of iron ore at the contact of the marble and volcanic rocks have been mined at many places, residual clay is exposed in most of the mines and marble is seen in only a few of them. Elsewhere the weathered marble has a dark-brown skin and weathers to a deep-red granular clay soil, as may be seen in the Wakefield and Priestland Valleys.

The marble is everywhere closely folded. In the linear belt that extends from the vicinity of Taylorsville and Shrivers Mill northeast to the Maryland-Pennsylvania State line, the folds are overturned to the southeast and the marble dips northwest. West and southwest of a point near Medford, the folds are overturned to the northwest and the beds dip southeast. The marble occupies valley floors, and only in a few places crops out on or near hilltops. The marble crops out on either the southeast or northwest side of a valley, depending on whether the dips are southeast or northwest respectively and the marble is protected from erosion and solution by the overlying volcanic rocks. For this reason marble quarries are located on the side of the valley where the marble is overlain by volcanics that dip away from the valley.

The marble-volcanic contact therefore is not generally exposed on the side of a valley where the rocks dip into the valley. Plate 12A shows a marble quarry southwest of Spring Mills where the marble dips northwest and has been quarried on the east face of a hill formed by Sams Creek metabasalt.

Marble is well exposed in road and stream cuts and in many quarries, most of which are no longer worked. Some of these quarries are described by Mathews and Grasty.[52] The general distribution of the marble and the location of quarries is shown in plate 27 of their report.

The thickest section of marble is exposed in the John S. Hyde quarry, located in a marble valley one-half mile wide, at a point one-half mile southwest of Wakefield Mills. The marble dips 40° SE. The top beds on the northwest side of the quarry, near the Sams Creek metabasalt, are mottled pink, green, and white marble. The lower beds, which are quarried, are fine-grained white and gray-banded marble. Wakefield marble is well exposed in the quarries of the Lehigh Portland Cement Company, formerly operated by the Tidewater Portland Cement Co., at Union Bridge. The quarries are south of Little Pipe Creek in Frederick County. The marble there strikes N. 10° E. and dips 45° SE. It is infolded or interbedded with volcanic rocks, and on the east side dips under blue and purple volcanic slate that makes a hill east of the northern and oldest quarry. The quarry that was worked in 1936 lies south of a fault which locally, at the quarry, strikes N. 70° E. The fault offsets the formations so that the rocks south of the fault have been moved east in respect to those on the north side. The fault is marked by a breccia of marble and slate in a zone in which the rocks are slickensided and kneaded.

The Wakefield marble in outcrops near Millers and Hoffman's Mill, Carroll County, is a crystalline, blue marble containing blue quartz grains. Schistose layers in the marble contain muscovite and chlorite. The marble weathers to a rusty, earthy, siliceous skeleton. Throughout most of Carroll and Frederick Counties, the Wakefield marble is a pure, white, finely crystalline marble composed of calcite or dolomite with few impurities. The beds near the contact with the volcanic rocks are white or blue marble, mottled with pink and green. Marble exposed in a quarry and in road cuts at Linganore, Frederick County, contains quartz grains and in that respect resembles the marble near Millers and Hoffman's Mill. The marble at Linganore is white and contains interbedded white quartzite. The mottled marble has been called "variegated" or "calico" limestone[53] or "copper" marble. It may be as much as 50 feet thick. The variegated marble crops out widely in western Carroll County and in Frederick County where outcrops are shallow and the lower beds of white marble are not exposed. Blue banded marble is interbedded with white marble in some places and is of common occurrence in the region northeast of Westminister. The following section was measured in that area in a quarry located one mile southwest of Bixler. There, the marble strikes N. 30° E. and dips 70° NW.

[52] Mathews, Edward B., and Grasty, J. S., op. cit. Md. Geol. Surv., vol. 8, pt. 3, pp. 350–377, 1909.

[53] Mathews, Edward B., and Grasty, J. S , op. cit., p. 353, 1909.

Section of Wakefield Marble in a Quarry 1 Mile Southwest of Bixler

	feet
Blue slate (northwest side)	
White dolomite with some blue bands	35
Mottled blue marble	10
Dolomite, weathered buff	5
Blue banded schistose marble	5
Marble, mottled blue and white	50±

Greenish-blue volcanic slate, with a 3 foot layer of sheared blue marble and purple and white marble breccia, occurs close to the contact with the mottled blue and white marble.

In thin section the white marble is seen to be made up of calcite, doubly-twinned, in a cloudy groundmass of fine calcite. The calcite crystals lack the clear interlocking outlines characteristic of the Cockeysville marble. Accessory minerals are zircon, titanite, and tourmaline. In thin section the blue banded marble is seen to be composed of calcite clouded by fine impurities and quartz. The blue bands are formed by fine scales of muscovite, chlorite, and fine iron dust. Secondary calcite and chlorite fill veins.

The "variegated" marble that lies near the contact with the volcanic rocks simulates a marble breccia. It is made up of irregular angular-shaped blocks of white, green, and pink marble with shiny green chlorite schist parting planes. Such marble is exposed just east of Wakefield and one-half mile west of Dunkard Church. In the Shriver quarry near Spring Mills, where the marble dips steeply northwest under purple volcanic slate (Pl. 12A), the marble contains bands of epidote near the slate, and the slate at the contact with the marble is sheared. In a quarry at Linwood the "marble breccia" is infiltrated with jasper. Zones in the marble contain shiny green slate enclosing lenticular blocks of marble. Adjoining layers are pink laminated marble with slickensided slate partings. Mathews[54] described the color variations in the marble near the volcanic contact and stated that they were produced by infiltration of solutions carrying manganese and iron from the adjoining volcanic rocks along zones of fracture in the marble. He pointed out that fracture zones and slickensides indicate movement and faulting at the contact of the marble and volcanic rocks.

No complete section of marble was found in Carroll and Frederick Counties. The thickness of marble near Union Bridge was estimated to be 150 feet.

Silver Run Limestone

The Silver Run limestone crops out in northern Carroll County, chiefly in an area north and west of Union Mills, and in an area that extends from the vicinity of Frizzelsburg south to New Windsor, Linwood, and McKinstry's Mill. In the region between Union Mills and Frizzelsburg, Silver Run limestone crops out in scattered small areas. The limestone underlies valleys, in which it is poorly exposed. Limestone exposed along Silver Run and in the vicinity of McKinstry's Mill is overlain by the Ijamsville phyllite. Elsewhere Marburg schist overlies the limestone. The

[54] Mathews, Edward B., and Grasty, J. S., op. cit., p. 353, 1909.

limestone is exposed in small quarries in the valley of Silver Run, near Arters Mill and nearby on Big Pipe Creek, and in the valley of Meadow Branch at Weishaars Mill. The largest area of the limestone in Carroll County is north and northwest of Walls Mill, along Roop Branch and Wolfpit Branch. It has been quarried on Sams Creek near McKinstry's Mill and on Little Pipe Creek in the area northwest of New Windsor.

The Silver Run limestone is blue, thin-bedded, and finely crystalline. It has blue slate partings, is closely folded, and is veined with calcite and quartz. The upper beds are calcareous slate. It weathers to a clay soil containing blue slaty fragments which weather buff. Where no outcrops are found, the limestone has been mapped by the presence of these slaty fragments in the soil. It may underlie other valleys in which it is not mapped where neither residual slate fragments nor limestone outcrops were found.

VOLCANIC SERIES

General Description.—The volcanic series includes the Sams Creek metabasalt, the Libertytown metarhyolite, the Ijamsville phyllite, and the Urbana phyllite. The Sams Creek metabasalt is more widely distributed in the eastern part of the belt of the volcanic series, and occurs only in small areas in the western part. The Libertytown metarhyolite, including metaandesite and acidic tuffs, is more widely distributed in the western part of the belt of the volcanic series. The Ijamsville phyllite, which is regarded as having been derived largely from tuff of the acidic volcanic rocks, is infolded with all the other members of the volcanic series. The Urbana phyllite overlies the Sams Creek metabasalt in the southwestern part of the area of the volcanic series, and contains some pyroclastic beds. Quartzites of pyroclastic and clastic origin are interbedded with and overlie the volcanic series. The volcanic series overlies the Wakefield marble and in places the Silver Run limestone, and underlies the albite-chlorite schist facies of the Wissahickon formation and the Marburg schist.

Sams Creek Metabasalt

The Sams Creek metabasalt crops out in a linear belt which extends southwestward from the Maryland-Pennsylvania State line, in the vicinity of Lineboro, to a point one mile northeast of Taylorsville. The belt lies one mile northwest of Manchester and passes through Westminster. The metabasalt overlies Wakefield marble and underlies the albite-chlorite schist of the Wissahickon formation.

In the region west and southwest of this linear belt, the metabasalt has a curvilinear strike which is common to the underlying Wakefield marble. The metabasalt extends from a point $1\frac{1}{2}$ miles west of Westminster, west and southwest to Linwood and the vicinity of Oak Orchard. The metabasalt is repeated several times across the strike and is overlain by the Ijamsville phyllite. Metabasalt crops out again southwest of Union Bridge in an area just west of the town, in small areas southwest of Unionville, at Linganore, and south of Dollyhyde Creek. In these areas metabasalt is interbedded with the Libertytown metarhyolite and metaandesite, and is overlain by the Ijamsville phyllite. From the vicinity of New London, southward to New Market and Monrovia, the metabasalt covers a wide area and is overlain by the Urbana phyllite. The metabasalt with similar relations extends southward to Green Valley and to the region east of Centerville. West of Parrsville, metabasalt is exposed in several narrow upfolds in the Marburg schist. The metabasalt is interbedded with blue and green volcanic schist, which in part contains chloritoid. In the region northeast of Westminster, volcanic schists form a large part of the formation but they are not separately mapped. The metabasalt is closely folded and injected by veins of quartz and epidote. In the linear areas that pass through and lie just northwest of Westminster, the metabasalt dips northwest. West and southwest of a point a mile west of Avondale, the dips are to the southeast.

Metabasalt forms hills between valleys underlain by Wakefield marble. The best exposures are in quarries, stream valleys, and road cuts on highways. Fresh exposures occur at many points on State Highway 31 between Westminster and New Windsor. It is well exposed on that highway southwest of New Windsor in a belt that lies just east of Englars Mill, where the highway trends across the strike of the metabasalt. Here it crops out in steeply inclined rocky pinnacles (Pl. 12B). It crops out also on Sams Creek east of McKinstry's Mill, on the tributaries of Sams Creek in the area south of Union Bridge, near Linganore, on Bens Branch near New London and to the southward in the vicinity of New Market. The metabasalt weathers to a deep clay soil which is colored red because of the high iron content of the rock.

Metabasalt, or as it is commonly known "greenstone," is a grayish-green schistose to massive rock spotted with light-green, white, or pinkish knots, which are amygdules filled with quartz, calcite, or green epidote. The constituents of the rock are epidote, hornblende, chlorite, quartz, remnants of feldspar, and magnetite. All gradations occur from a massive amygdular rock with inconspicuous schistosity through a schistose variety in which the amygdules are drawn out into elliptical form, to fissile slate without recognizable volcanic characteristics in which amygdules are represented by flattened blebs or stringers. The metabasalt in which the amygdules are filled with calcite weathers to a "worm-eaten" porous green schist with cavities produced by the removal of the calcite fillings. The cavities are partly filled with brown iron oxide and have a green lining of chlorite. Amygdules of epidote and quartz, being harder than the groundmass, are exposed on the weathered surface of the metabasalt as knots.

In thin section the massive amygdaloidal greenstone is seen to be made up of a groundmass of feldspar, epidote, quartz, and magnetite, with phenocrysts of feldspar and hornblende, some of which show cores of original augite. The feldspars of the groundmass have an ophitic arrangement and possess crystal outline. Augite is largely altered to green fibrous hornblende (uralite) and to epidote. The amygdules contain needles of hornblende and grains of epidote, calcite, quartz, and albite. The feldspar of the groundmass is albite, formed from more calcic feldspars by the liberation of lime which was used in the formation of epidote. Epidote occurs not only in grains but in veins. The accessory minerals are magnetite, hematite, ilmenite, titanite, and pyrite.

The blue and green schist layers are fine-grained chlorite and sericite schists. In thin section they are seen to be dusted with fine iron oxide, and owe their color difference to the state of oxidation of the iron content. In part they contain dark prisms of chloritoid in single fibers and sheaves. These schists resemble blue and green schists in the Ijamsville phyllite and Marburg schist.

Libertytown Metarhyolite

The Libertytown metarhyolite, shown on the geologic map of Frederick County as metarhyolite and metaandesite, occurs in Frederick County in a belt that lies south and southwest of Union Bridge and north of U. S. Highway 40. The eastern edge of the belt extends into Carroll County in the vicinity of McKinstry's Mill. The metarhyolite is interbedded with blue amygdaloid, probably of andesitic composition, and blue, green, and purple tuffaceous slate. This series of acidic volcanic rocks is commonly more schistose than the metabasalt, but retains volcanic textures in large part. The Libertytown metarhyolite overlies Wakefield marble, and interfingers with the Sams Creek metabasalt and Ijamsville phyllite. The metarhyolite is well exposed west and south of Unionville, where it crops out at several points on State Highway 26 east of Libertytown, and on Dollyhyde Creek.

The metarhyolite is a dense cryptocrystalline rock, purple, bluish black, or red in color. It has macro-phoenocrysts of pink or white feldspar and glassy quartz in a dense groundmass. Its weathered surface has a much lighter color. It is interbedded with blue and purple metaandesite containing amygdules commonly filled with calcite having an outer film of sericite or chlorite. The calcite is white, pink, or green in color. Amygdules up to one inch in diameter have been found. In weathered outcrops the calcite has been removed by solution and the rock is full of holes, partly filled with brown iron oxide, sericite, or chlorite. At many places the metaandesite has been compressed into a dense blue or purple schistose rock with flattened shiny green or gray blebs, composed of chlorite or sericite. The blebs are visible on cleavage surfaces and are elongated in the direction of the lineation. In thin section the amygdular variety shows calcite fillings much broken and surrounded by chlorite and sericite. The groundmass is largely hematite, calcite, quartz, and sericite, with feldspar laths still remaining. The amygdules are commonly drawn out and arranged in irregular bands.

Metarhyolite and metaandesite are interbedded with blue, purple, and green slates which have lost all volcanic textures by deformation. The slates are injected by quartz veins along the layering, closely folded, and cut by a closely-spaced transverse cleavage. The slates in outcrops may be of one color or banded, such as green banded with blue. In thin section the purple slate is seen to contain ottrelite. The blue slate contains albite intergrown with fine muscovite fibers in a matrix of muscovite and fine black iron oxide. In some specimens feldspar phenocrysts are partly replaced by quartz and chlorite and occur as knots in a matrix of finely divided hematite, fine grains of quartz and sericite, and chlorite fibers.

Analyses of Volcanic Slate from Carroll and Frederick Counties

	I	II	III	IV
SiO_2	47.85	58.41	—	—
Al_2O_3	16.04	22.27	—	—
Fe_2O_3	20.19	8.31	—	—
FeO	—	—	—	—
MgO	6.07	0.73	—	—
CaO	0.60	0.09	—	—
NaO_2 }	3.94	6.42	1.51	.73
K_2O }			4.18	6.02
H_2O^+ }	5.07	3.66	—	—
H_2O^- }				
	99.76	99.89	5.69	6.75

I.—Slate, Johnsville, Frederick County. Analyst, Zies. Md. Geol. Surv., vol. 8, Limestones of Maryland, p. 395, 1909.

II.—Slate, quarry of Portland Tidewater Cement Co., Frederick Co. Analyst, Zies. Idem.

III.—Gray slate, Clemsons quarry, Union Bridge, idem, p. 355 and 399.

IV.—Purple slate, Union Bridge, idem, p. 355.

Ijamsville Phyllite

The Ijamsville phyllite lies west and southwest of Westminster and extends southwest from Frederick County into Montgomery County at a point one mile south of Green Valley. In the vicinity of Shriver's Mill, the phyllite is bordered on the southeast by the Wissahickon albite-chlorite schist and west and southwest of Taylorsville by the Marburg schist. From a point near New Windsor westward to Bark Hill, a band of phyllite follows the north border of the Sams Creek metabasalt and Wakefield marble. In the region southwest of Union Bridge, the phyllite is folded intimately with the metabasalt and metarhyolite. Near Ijamsville and south of Monravia, the phyllite is surrounded by Urbana phyllite. Along the western edge of the Martic overthrust block, east of the Frederick Valley, the phyllite forms a narrow belt that extends from the vicinity of Ladiesburg, at the border of the Triassic rocks, southwestward to Monocacy River, 2 miles north of the Frederick County line. The Ijamsville phyllite is exposed in many stream valleys and road cuts. It may be seen in quarries near Ijamsville, where it was quarried for roofing slate.

The rock is a blue, green, or purple phyllite injected by quartz, closely folded and with a closely spaced transverse cleavage. In large part it shows no volcanic characters, but in places it contains flattened blebs which indicate that the phyllite is derived from a tuff. At such places it resembles purple, green, and blue slates of the Libertytown metarhyolite and blue schist beds in the Sams Creek metabasalt. It contains ottrelite at many places, as east of McKinstry's Mill, southwest of Englars Mill, and east of Marston. At many places, as in the neighborhood of Libertytown, it has beds of soft, blue, fine-grained phyllite of uniform texture and dull luster. The layers are finely crenulated. The intersection of the closely spaced slip cleavage with the layers give the rock a finely wrinkled surface. The rock breaks into elongated wooden-like blocks bounded by the layering, the cleavage, and joint planes that are at right angles to the strike of the cleavage. The blue color is due to fine hematite dust. This rock is used locally as a whetstone.

In thin section specimens of closely crumpled, green, chlorite-quartz phyllite from east of Uniontown and north of Linganore show finely folded feebly pleochroic chlorite and fine muscovite blades, scanty feldspar, zircon, and fine magnetite dust. The presence of quartz in lenticles of uneven grain and of streaked-out chlorite suggests a phyllonitic structure. It is probable that ilmenite and chlorite and fine magnetite dust were derived from the alteration of biotite. The presence of leucoxene derived from ilmenite also suggests retrogression. Thin sections of blue Ijamsville phyllite from southeast of Unionville suggest that the phyllite was derived from an albite schist which was differentially deformed; that the albite was rotated and the matrix was recrystallized to muscovite and iron dust.

Origin of the Volcanic Series

The volcanic series has been greatly deformed under conditions of regional metamorphism. It comprises amygdaloidal and porphyritic flows which are somewhat schistose but in which the metamorphic changes are largely chemical; the original minerals have been changed in part or completely, but the effusive textures remain and their effusive origin is evident. These flows are interbedded with phyllites that not only contain new minerals but have lost all volcanic textures. Amygdaloidal and porphyritic rocks are interbedded with such phyllites, which resemble the Ijamsville and Urbana phyllites. The constituents of these phyllites are sodic feldspar, muscovite, chlorite, iron dust, ilmenite, and titanite. Calcite is present in the Urbana phyllite. The sodic feldspar is secondary to an original lime-soda feldspar. Muscovite is derived from potash feldspar; chlorite, iron dust, ilmenite, and titanite from titaniferous biotite. The blue-green and purple phyllites have been referred to as altered acidic volcanic rocks. Their high titanium content however relates them to more basic volcanic rocks in which titanium compounds, in the form of ilmenite or as a component of biotite, are of common occurrence. It has been assumed that the phyllitic rocks in the volcanic series were derived from tuffs. It is possible that some of them were derived from fine-grained flows.

Quartzites

Quartzites are interbedded with all of the formations of the volcanic series and overlie some of them. Quartzite in the Urbana phyllite and the Sugarloaf Mountain quartzite will be discussed later.

Most of the quartzite is a clastic sediment, but quartzite interbedded with pyroclastic slate may be in part of tuffaceous origin. At places on Hazelnut Run and Bens Branch, northwest of New Market, and south and west of New London, green banded porous-weathering quartzite is interbedded with the Sams Creek metabasalt. On Hazelnut Run thin white quartzite in the metabasalt lies not far above the contact of the metabasalt and Wakefield marble. Just south of New London, a mass of hard white quartzite forms a hill cut through by State Highway 75. The quartzite appears to directly overlie the metabasalt. The quartzite forms an irregular-shaped area with curving strike, and extends southeast and east. At a point 1 mile southeast of New London, where the quartzite trends east, it passes into the Ijamsville phyllite.

In the vicinity of Libertytown and south and west of that town, quartzites form two ridges which unite into a single ridge southwest of the town. Horsehead Rock is at the northeast end of the eastern ridge. At the junction of the eastern and western ridges, just north of State Highway 75, a high ledge of quartzite is called Lovers Rock. Southward the quartzite forms a prominent wooded ridge, $\frac{3}{4}$ mile long, on the east side of the highway. The ridge is known as Piny Hill, and a rocky peak at the south end, called the Pinnacle, stands 60 feet above the highway. The east face is much steeper than the western side. The quartzite overlies Ijamsville phyllite and blue volcanic slate. The sequence of the quartzite beds in these ridges is:

Fine white quartzite, 30 feet thick.
White sericitic quartzite, composed of rounded glassy quartz grains in a red ferruginous siliceous cement; veined by quartz. These two quartzites form Lovers Rock, Piney Hill, and the Pinnacle.
Dark quartzite, which forms Horsehead Rock and slopes of other ridges.
Blue-purple quartzite, some layers of which weather porous; 20 feet thick.
Blue volcanic slate, containing thin quartzite beds with slate pebbles.
Marble.

In Piney Hill, the uppermost white quartzite and the quartzite composed of glassy quartz grains dip east in an overturned syncline. These beds resemble in lithologic character and sequence the Sugarloaf Mountain quartzite. Quartzite lower in the series, interbedded with volcanic slate, crops out south of the Pinnacle on State Highway 75 and in Towns Branch west of that road. This quartzite is fine grained and green, and some layers weather porous. Similar quartzite crops out at points south of State Highway 26, $1\frac{1}{2}$ miles west of Unionville. North of Libertytown and near Johnsville, the Ijamsville phyllite has beds of purplish-red and dark-blue quartzite and banded blue slaty quartzite. The quartzite is composed of fine angular to rounded quartz grains in a siliceous cement. Some of the ferruginous beds are bluish black in color. In places the quartzite contains pebbles of slate, rhyolite, and jasper. These quartzites are interbedded with the Ijamsville phyllite, and are part of the acidic volcanic series.

Quartzite forms a series of linear ridges that trend south from a point $1\frac{1}{2}$ miles due west of Union Bridge. The quartzites pass near Mountain View School, cross State Highway 75, and continue south for a distance of $1\frac{1}{2}$ miles. The strike bends locally where the highway crosses the quartzite near Mountain View School. It overlies blue volcanic slate, and dips east in tightly closed synclines that are overturned to the northwest. The pitch of the folds is 35° SE.

Quartzites infolded with volcanic rocks are well exposed along a road that runs south and east from McKaig and crosses Linganore Creek $1\frac{1}{2}$ miles southeast of that village. The uppermost beds crop out in the valley of the creek. The sequence of beds for a distance of half a mile northwest of the road bridge over the creek is:

Massive white quartzite with thin black slate bands; 20 feet exposed at the creek.
Sericitic quartzite.

Amygdaloidal greenstone and interbedded blue slate.
Porous-weathering quartzite.
Blue bleby volcanic slate.
Blue sericitic banded quartzose slate.
Sericitic quartzite.
Green sericitic quartzite.
Blue spotted slate.

The upper white quartzite exposed at Linganore Creek may be at the same horizon as the upper beds in the synclines southwest of Union Bridge and south of Libertytown. They resemble some of the lower beds of the Sugarloaf Mountain quartzite. The lower quartzites are interbedded with the volcanic series.

Urbana Phyllite

The Urbana phyllite overlies the Sams Creek metabasalt in an area in the southern part of Frederick County. North of U. S. Highway 40, from a point 1½ miles east of New Market westward to a point one mile east of Bartonsville, the phyllite is in narrow infolds in the metabasalt. South of that highway it extends southward in three parallel belts to the Frederick-Montgomery County line. The western of these belts is the widest and contains the synclinal mass of Sugarloaf Mountain quartzite which overlies the Urbana phyllite. The Urbana phyllite on the east side of the Sugarloaf Mountain quartzite extends northward from Stronghold, through Thurston, and encircles the north end of the quartzite mountain. On the west side of the mountain it passes east of Park Mills and extends southward to the Frederick County line. The phyllite also extends northeast up the Valley of Furnace Creek into the headwaters of Bear Branch within the Sugarloaf Range. On the west side of the main belt of Urbana phyllite it is in contact with Ijamsville phyllite. From a point two miles south of Park Mills to the Frederick County line, the Triassic sedimentary rocks overlie the phyllite on its western border. On the east side the Urbana phyllite lies adjacent to the Ijamsville phyllite.

The Urbana phyllite contains interbedded quartzites, some of which are ridge making and are shown on the Frederick County geologic map. North and northeast of Urbana, the quartzites have a northeast linear trend; southwest of that town the strike curves and conforms to the trend of the overlying Sugarloaf Mountain quartzite. North of U. S. Highway 40, the phyllite grades northward into the Ijamsville phyllite, and quartzites in the upper part of the Urbana phyllite pass into the Ijamsville phyllite.

The Urbana phyllite is exposed along the Baltimore and Ohio Railroad from a point one-fourth mile east of Reels Mill to a point one-half mile west of Ijamsville, and again, to the east, from a point one-half mile east of Ijamsville to Monrovia. It is well exposed on U. S. Highway 240 in the vicinity of Urbana. It crops out east of Centerville on Bennett and Little Bennett Creeks, on the north and east side of Sugarloaf Mountain. South and west of that mountain, it crops out on Furnace Branch and on Bear Branch westward to the vicinity of Park Mills.

The Urbana phyllite is a green muscovite quartzose rock with calcareous layers that weather into rusty porous bands. Calcareous layers occur chiefly in the lower part of the formation but also at higher horizons. The thickest calcareous layer, which has been mapped where it crops out at a point $\frac{3}{4}$ mile south of Park Mills, is a green schistose marble. Similar marble, but more impure, crops out to the northeast at several points on Bennett Creek.

In thin section the constituents of the green phyllite are grains of feldspar and quartz, muscovite and chlorite blades, and scanty calcite. These minerals are dusted with iron oxide. It contains also titanite and zircon. The green phyllite is interbedded with quartzose phyllite, slate, and thin quartzites which vary in character at different horizons in the formation. In the region west of New Market the lowest beds that overlie the metabasalt comprise blue banded slate with quartz grains, purple fine-grained quartzite, and black quartzite with grains of glassy quartz and epidote. In places, such as 2 miles west of New Market, the lowest beds are a fine gray feldspathic quartzite containing grains of jasper, epidote, and blue quartz. The blue banded slate resembles tuff. In some places the Sams Creek metabasalt grades upward into a schist with quartz and epidote grains, which is the basal part of the Urbana. These lower beds are interlayered with green calcareous phyllite and grade upward into dark-green quartzite and massive white quartzite.

Northeast of Park Mills, on the north side of Sugarloaf Mountain, green phyllite of the Urbana is interbedded with layers of green banded slate, thin layers of metabasalt, and associated green sericitic quartzite. These beds underlie the green and white quartzites in the upper part of the formation. It seems probable, therefore, that the Urbana phyllite is in part derived from tuffaceous beds related to the underlying metabasalt.

The upper quartzite beds of the Urbana phyllite are exposed on the flanks of Sugarloaf Mountain west of Stronghold and Thurston and southeast of Park Mills. There the upper quartzites comprise fine-grained, arkosic quartzite with dark slate bands and dark-green, rusty and purple-weathering, sericitic quartzite containing grains of coarse glassy quartz, overlain by white quartzite.

At Park Mills massive white quartzite mapped in the Urbana makes a prominent ridge northeast of Bear Branch. Southwest of Park Mills it is cut off by a normal fault. The quartzite is in part composed of densely packed, rounded grains of glassy quartz and resembles the Sugarloaf Mountain quartzite. The exposures are 200 feet thick and may represent a tightly closed syncline of Sugarloaf Mountain quartzite west of, and parallel to, the Sugarloaf Mountain syncline.

The sequence of beds in the Urbana, as determined along Brush Creek in the neighborhood of Reels Mills, is:

Hard white sericitic quartzite with quartz grains; makes ridges.
Fine-grained green sericitic quartzite.
Thin green slate and dark ferruginous quartzite; weathers porous.
Green micaceous quartz phyllite, in part calcareous and weathers rusty banded.
Ijamsville phyllite.

The upper white quartzite makes prominent ridges south and north of Brush Creek and extends northeast to Linganore Creek, where it is well exposed in the creek valley and on the neighboring hills at a point $2\frac{1}{2}$ miles northeast of Bartonsville.

There the thicker quartzites make a series of falls in the stream. The beds dip east, are repeated, and appear to be folded into a syncline.

The sequence of beds in the Urbana as interpreted east of Bartonsville is:

Massive white quartzite.
White quartzite with fine rounded quartz grains with ferruginous cement, repeated in two ledges each 40 feet thick; 200 feet interval between them, covered.
Sericitic quartzite.
Hard ferruginous quartzite.
Sericitic blue slate-banded quartzite.
Green phyllite.

All of these beds are mapped as part of the Urbana phyllite, but the upper white quartzite, exposed here and on Brush Creek, resembles the Sugarloaf Mountain quartzite. They are in the general strike of the Sugarloaf syncline and may be beds equivalent to the Sugarloaf Mountain quartzite enclosed in a northern extension of that syncline.

Sugarloaf Mountain Quartzite

The Sugarloaf Mountain quartzite overlies the Urbana phyllite and forms Sugarloaf Range, which includes a ridge north of the peak and a ridge west of the main mountain. The Sugarloaf Mountain quartzite comprises two thick hard ledge-making quartzites separated by interbedded softer sericitic quartzite and slaty beds, which are poorly exposed. Beds similar to the Sugarloaf Mountain quartzite, which crop out at Park Mills, on Brush Creek and Linganore Creek, and south of Libertytown, have been placed in the Urbana phyllite but may be Sugarloaf Mountain quartzite. The crest of Sugarloaf Mountain peak, which is about 1300 feet in altitude and stands 800 feet above the general level of the Piedmont upland, is encircled by cliffs of the upper white quartzite which are visible for a long distance.

The mountain is easily accessible from the south by a private automobile road, built by Gordon Strong the owner of the southern end of the mountain. The private road, which leaves the public road that runs along the foot of the mountain west of Stronghold, is open to the public most of the time. The road ends at a parking place at a point about 300 feet below the summit. The parking place is equipped with tables and other facilities for picnic parties. The terminal parking place is on west-facing cliffs of the lower quartzite of the Sugarloaf Mountain formation and offers a fine view to the west. A south-facing viewpoint has been constructed at a ledge of the same quartzite at a lower point on the road (Fig. 29). This quartzite was quarried by the owner, in a ledge just east of the viewpoint, for road material and as a building stone for the houses on the property. From the parking place at the terminus of the private road a well constructed foot path with steps at the steeper parts leads to the summit. The 150-foot cliff that forms the summit is broken by a narrow ravine filled with large talus blocks of quartzite, and the path ascends this ravine. The top of the mountain is nearly flat quartzite and has a few low trees. The top of the cliffs offers a wide view of Frederick Valley and glimpses of picturesque cliffs of quartzite in the wooded mountain nearby (Pl. 13).

The section of the Sugarloaf Mountain quartzite is:

Composite Section of Sugarloaf Mountain Quartzite

	feet
Sugarloaf Mountain quartzite:	
Thick-bedded white quartzite, composed of tightly packed round glassy quartz grains (upper cliff maker)	200±
Concealed; in part softer quartzite and banded shale	70±
Hard thin-bedded, current-bedded white quartzite composed of tightly packed round dark glassy quartz grains, some beds stained bright red by iron oxide and contain thin seams of hematite (lower ledge maker)	50±
White and red-stained granular quartzite and thick-bedded crumbly white granular quartzite, composed of round quartz grains, interbedded with thin layers of slate	50±
	370±
Urbana phyllite:	
Coarse granular quartzite with round dark glassy quartz grains and fine pebble conglomerate (10 feet thick) interbedded with spotted volcanic slate.	

The Sugarloaf Mountain quartzites grade downward into the Urbana phyllite, the upper part of which contains quartzite with round glassy quartz grains similar to those in the Sugarloaf Mountain quartzite.

The upper cliff-making quartzite of the formation forms a gently southeast-dipping plate that caps the main peak of Sugarloaf Mountain. It has high white cliffs on its west and south sides (Pl. 13 and fig. 17). The lower ledge-making quartzite forms a bench with low cliffs on the west slope of the mountain at about 1000 feet altitude, and a similar bench with ledges on the southeast side at about 940 feet altitude. Ledges of this lower quartzite make irregular-trending rocky spurs that descend the south slope of the mountain to its foot. These ledges are shown on the detailed map of Sugarloaf Mountain (Fig. 16).

The mountain is synclinal and the fold is overturned toward the northwest. The upper cliff maker is present apparently only on the main peak of Sugarloaf Mountain. It is made up of two layers; the upper 100± feet is massive, well-bedded vitreous white quartzite; the lower 100± is thinner-bedded and largely white, with some red streaked quartzite at the top and with purplish red and laminated quartzite at the bottom. The upper cliff-making quartzite that caps the peak dips gently east and is the west limb of the syncline. The east limb is represented only in scanty outcrops at the east side of the crest, where the quartzite is much crushed and veined with quartz and strikes N. 60° E. and dips 10° NW.

The lower ledge-making quartzites of the formation are closely folded at the south end of the syncline, and are exposed in ledges that make spurs on the south slope of the mountain. On the east side they form a northeast-trending ledge at 940 feet elevation with a cliff on the east side. On the west side of the mountain they make ledges with west-facing cliffs at the upper parking place on the private road. Their detailed structure, as tentatively determined, is shown in the sketch of the mountain viewed from the road west of Stronghold (Fig. 28).

North of the peak, Sugarloaf Mountain is densely wooded and is traversed only by overgrown trails. North of the terminus of the private road, the lower quartzite forms a cliff at an altitude of 1050 feet, which extends to the saddle north of the peak. North of the saddle this quartzite makes the main northeast trending crest of the

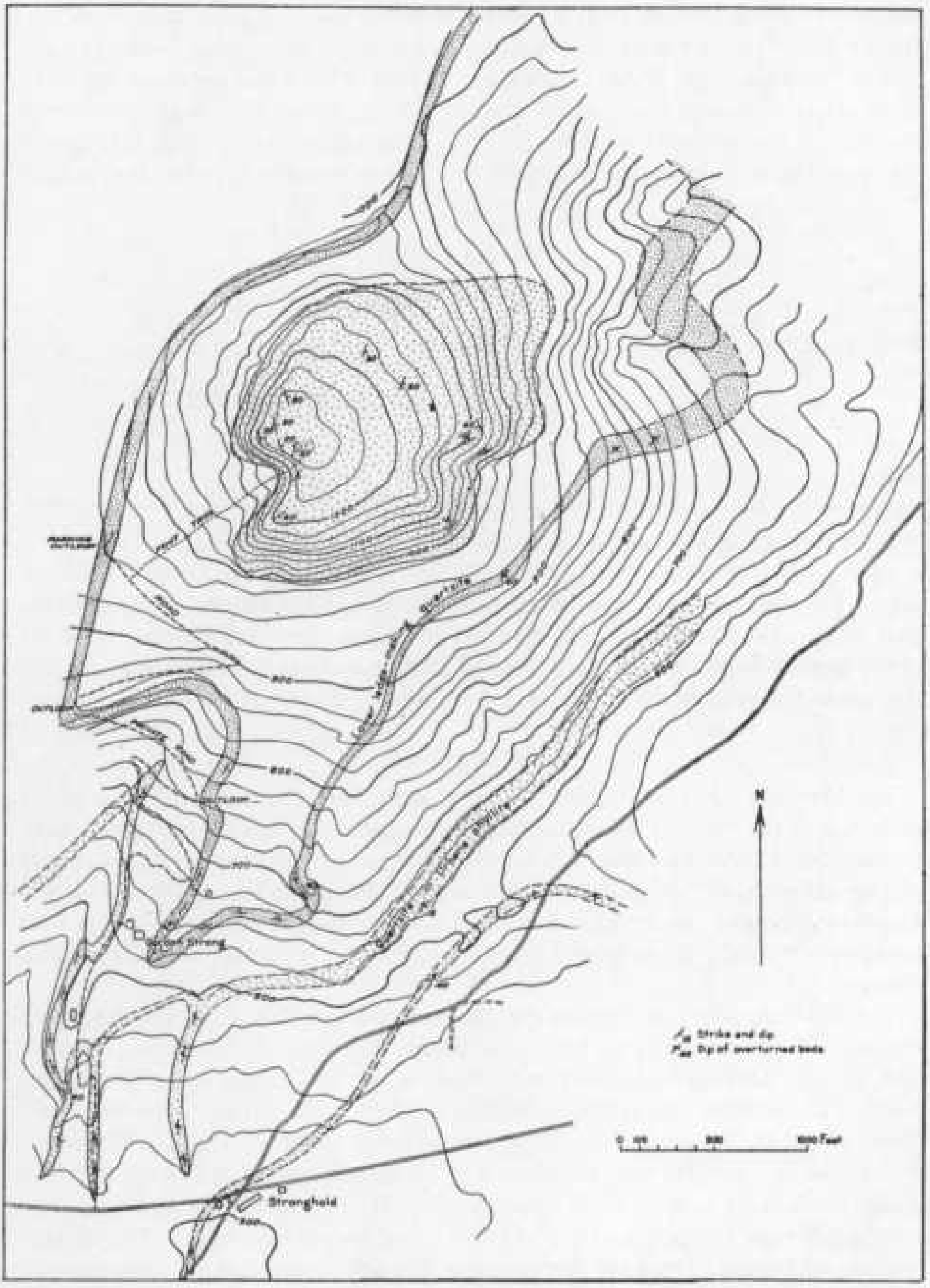

FIG. 16. Geologic map of Sugarloaf Peak. Contoured map from map surveyed by Richard F. Flint in 1924–25 for Gordon Strong. Geology by Anna J. and George W. Stose. Quartzite capping the peak and lower ledge-making quartzite of the Sugarloaf Mountain quartzite shown by denser stipple pattern.

mountain and the curving ridge which encircles the head-waters of Bear Branch at the north end of the mountain. West of Thurston, an outer ridge, parallel to and east of the main ridge, is also composed of the lower ledge-making quartzite. The quartzite in this outer ridge, which dips 30°–50° SE., is apparently the overturned east limb of the Sugarloaf syncline (Fig. 29). The softer quartzite beds that overlie the lower ledge-making quartzite, enclosed in the syncline between the parallel

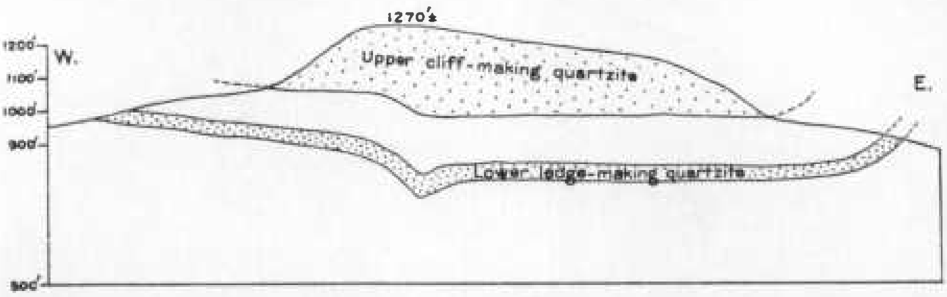

FIG. 17. Cross section through capping Sugarloaf Mountain quartzite on Sugarloaf Peak.

ridges, are poorly exposed and are covered by talus of the harder quartzite of the west limb. The lower ridge-making quartzite forms high knobs northwest of the headwaters of Bear Branch (Pl. 13B) and crops out in white cliffs where it is cut through in the gorge of the branch at a sharp westward bend in the stream.

Marburg Schist

The Marburg schist in northern Carroll County lies north and northwest of the main belt of the volcanic rocks and Wakefield marble and east of the Triassic sedimentary rocks. Another area of the schist in the southern part of the county is west of the albite-chlorite schist of the Wissahickon formation and southeast of the Ijamsville phyllite. At the Carroll-Howard County line it forms a belt 7 miles wide that passes through Ridgeville and Mount Airy, and lies in part in eastern Frederick County.

The Marburg schist is a bluish-gray to silvery-green, fine-grained schist which contains either muscovite, chlorite, albite, and quartz or muscovite, chlorite, ottrelite, and quartz. Ottrelite schist occurs in Parrs Ridge in the vicinity of Ridgeville, north of Union Mills, and 1 mile east of Wentz. Where the ottrelite fibers are microscopic in size, the presence of ottrelite is detected only in thin section. In the coarse-grained schist, ottrellite may be detected in the hand specimen as fine specks which make the cleavage surfaces slightly rough. The Marburg schist contains magnetite or hematite dust and pyrite which weathers to red iron-oxide specks. The schist is injected with quartz along the layering, and is closely folded and has a pronounced cleavage transverse to the layers. In thin section the rock shows crumpled layers of twisted fibers of chlorite and muscovite around lenticular bands of granulated quartz. Small crystals of albite contain inclusions of fine grains of magnetite, which occurs also in the rock in porphyroblasts. The crumpled layers are displaced by the cleavage. The constituents are paracrystalline with the folding, but quartz and chlorite show post-crystalline deformation.

Quartzite in the Marburg Schist.—Quartzite and conglomerate form the upper part of the Marburg schist. The quartzites in the southern part of the schist area occur in large part in the vicinity of Parrs Ridge and Waterville. In northern Carroll County quartzites form a hilly tract 2½ miles wide (Fig. 4), which enters the county from Pennsylvania and extends southwestward for a distance of 10 miles to a point 2 miles south of Union Mills. Near Wentz these hills rise to 1000 feet in altitude. The best exposures of the quartzites are along the headwaters of South Branch of Conewago Creek, on Deep Run, and along State Highway 94 in the neighborhood of Wentz. When the map of Carroll County was published in 1928, the quartzites near Wentz were thought to be of Lower Cambrian age. Further work in Carroll County and in the adjoining part of Pennsylvania has shown that the quartzite is part of the Marburg schist (Fig. 4).

The lower quartzites of this group are dark ferruginous feldspathic quartzite and green sericitic quartzite in beds 10 to 15 feet thick. They are interbedded with blue and green slate and overlie blue and green Marburg schist. The green quartzite is composed of blue-white glassy and milky quartz grains in a matrix of quartz, sericite, and chlorite. It weathers rusty yellow, and is injected with quartz veins. The upper beds of this group are coarse-grained quartzite with beds of green conglomerate, 2 to 4 feet thick, and interbedded layers of finely sparkling black slate. The conglomerate is composed of quartz grains and somewhat flattened pebbles of quartz up to ½ inch in length in a matrix of dark-green mica and chlorite. In places it contains green slate pebbles. The rock is speckled with fine iron oxide. The conglomerate, where weathered, contains areas of rusty-brown honeycombed quartzite, made porous by the leaching out of ferruginous cement.

In the region southwest of Deep Run, only the lower quartzites are exposed. Northeast of that place the lower quartzites are overlain by the upper massive quartzites and conglomerate beds which cap the higher ridges in the vicinity of Deep Run and Wentz. The quartzites are closely folded into tight synclines, which are overturned toward the southeast near Wentz and toward the northwest near Deep Run. No good section of the quartzites is exposed in Carroll County. The quartzites near Wentz extend northeastward into Pennsylvania and there the following sequence of beds was determined along Codorus Creek, north of Brodbeck:[55]

Composite Section of the Quartzites at the Top of the Marburg Schist at Brodbeck, Pa.

	feet
Sheared conglomerate containing pebbles of quartz up to 3 inches in size, and hard white granular quartzite (conglomerate member)	25±
Green ferruginous quartzite and quartz schist; contains glassy quartz grains in lower part	50±
Thick-bedded white to ferruginous quartzite containing blue quartz grains and small pebbles; weathers porous and rust spotted	25±
Gray phyllite	20±
Thick-bedded granular white quartzite with blue quartz grains and shiny shale partings; in part ferruginous; weathers banded, porous, and rust spotted; interbedded gray slate in lower part	30±
	150±
Green phyllite or platy slate, rust spotted from pyrite (Marburg schist)	

[55] Stose, A. J., and Stose, G. W., Geology of the Hanover-York district, Pennsylvania. U. S. Geol. Surv. Prof. Paper 204, p. 44, 1944.

Quartzite in the southern part of the Marburg schist area is exposed near Waterville, Cover, and Woodville. The quartzites are thin and resemble the lower beds of quartzite in the northern area. They crop out rarely on the upland, where their presence is indicated by quartzite blocks in the soil. The quartzite is green and sericitic, and contains grains of blue quartz. The beds are 4 to 6 feet thick and are infolded or interbedded with quartzose chlorite schist.

Albite-Chlorite Schist Facies of the Wissahickon Formation

This facies of the Wissahickon formation occurs on the northwest side of the Peters Creek formation. The schist enters Carroll County from Baltimore County and extends from the north edge of Carroll County for a distance of 30 miles southwestward across the county into Howard County. It forms Dug Hill Ridge and the northern part of Parrs Ridge in the vicinity of Warfieldsburg. Southeast of Dug Hill Ridge and near Westminster, it overlies the Sams Creek metabasalt. Near Millers and Hoffmans Mill, it overlies the Wakefield marble. In southwestern Carroll County, it is bordered on the west by the Marburg schist. Its greatest width in the county is 7½ miles extending from Westminster southeastward to the Peters Creek formation near Emory Church at the Baltimore County line. There it is cut across by West Branch of Patapsco River, which is followed by the Western Maryland Railroad. Good exposures along the railroad give a cross section of the formation. Fresh rock crops out also on South Branch of Patapsco River, which is followed by the Baltimore and Ohio Railroad.

The albite-chlorite schist facies comprises porphyroblastic albite schist, chlorite-quartz schist with scant or no feldspar, and quartzite. In this respect it resembles the three lithologic types of the oligoclase-mica schist facies east of the Peters Creek, but the metamorphism is of lower rank than that in the oligoclase-mica schist facies.

The albite schist of eastern Carroll County in the belt passing through Roller, Patapsco, and Barret is a sparkling schist with silvery-green biotite and chlorite and is characterized by poikilitic metacrysts of albite. It is the southwestward extension along the strike of the same type of albite schist which occurs in the vicinity of Parkton and Bentley in Baltimore County. The albite occurs in dull-white porphyroblasts that are up to 10 mm. in diameter and are most conspicuous on the rough surfaces normal to the plane of schistosity. These porphyroblasts are subhedral or anhedral with ragged boundaries, and are filled with inclusions of garnet, epidote, magnetite, biotite, and muscovite. Besides albite the rock contains biotite, chlorite, quartz, epidote, garnet, apatite, zircon, magnetite, pyrite, and titanite. Biotite is bleached and frayed at the ends and is altered to chlorite. It wraps around lenticular areas of fine-grained albite, epidote, and quartz. The quartz is variable in amount. Garnet occurs as poikilitic porphyroblasts containing quartz inclusions; where the garnet has been broken, the fragments are healed by secondary quartz.

The coarse albites with streams of inclusions were formed late in the folding or after it. The character of the included minerals indicates that they are relics of a period of higher rank metamorphism than that of the albite-chlorite schist. The change of the biotite to chlorite is a retrogressive process. From its microtexture and constituents, the albite-chlorite schist of Carroll County is thought to be a mesozone schist refolded in the epizone with the development of albite porphyroblasts which preserve in the included minerals the evidence of a previous crystallization of higher rank.

In the area northwest of the belt just described, the Wissahickon formation is a finer-grained chlorite-muscovite schist with fine-grained albite or ottrelite. Ottrelite schist is common in Dug Hill Ridge, east of Westminster, and in Parrs Ridge. The schist contains fine dust of hematite or magnetite, which is visible in thin section. Magnetite porphyroblasts are found in some specimens.

Quartzite in the albite-chlorite schist occurs chiefly at the base of the formation in northeastern Carroll County, but some beds of quartzite which appear to lie higher in the formation crop out in the region southwest of Westminster. Quartzite at the base (Fig. 4) is exposed in a narrow area that extends from Roller northward along Muddy Creek for a distance of 1½ miles. It crops out also between Millers and Alesia and west of East Branch of Patapsco River near Hoffmans Mill. Quartzite occurs in a narrow belt 6 miles long that extends from a point 1½ miles east of Lineboro, at the northern border of Carroll County, southwestward to a point one-half mile northwest of Manchester. It occurs also between Ebbvale and Melrose, on the northwest side of Dug Hill Ridge.

Where quartzite is present at the base, it directly overlies Wakefield marble; elsewhere the albite-chlorite schist rests directly on the Wakefield marble. The quartzite north of Roller is surrounded by albite-chlorite schist. In the other areas it lies in contact with Wakefield marble and grades up into the albite-chlorite schist. At Hoffmans Mill it is a white quartzite with blue quartz grains. The overlying albite-chlorite schist contains thin beds of quartzite. The quartzite near Ebbvale and in the belt northeast of Manchester is fine grained, and has a sugary texture. In exposures along Gunpowder Falls, the quartzite is 20 feet thick and contains blue quartz grains. A thin section of the quartzite at this locality shows a fine-grained mosaic of strained quartz with albite grains and muscovite and chlorite blades. Other constituents are zircon and magnetite.

In the region southwest of Westminster, quartzite, which appears to be interbedded with the albite-chlorite schist, crops out near Barrett, west of Day, and near Stone Chapel. Near Stone Chapel, it is a sericitic quartzite with glassy quartz grains. The maximum thickness exposed is 15 feet. There are thinner beds of quartzite in the adjoining silvery-green schist. The quartzite and schist dip 45° NW.

The albite-chlorite schist facies is closely folded and has a well-developed transposition cleavage which is parallel to the limbs of the folds. In places movement on these planes has drawn out or completely destroyed the folds. A later transverse cleavage cuts across the layers. Quartz injection parallel to the layers is closely crumpled, or drawn out into lenses which are parallel to the transposition cleavage. The massive layers are in more open folds in some outcrops, such as at points just southeast of Cranberry Station (Pl. 14A) and near Patapsco Station on South Branch of Patapsco River. In outcrops northwest of the station, the massive beds, which include quartzite, are folded into close recumbent folds. Recumbent folds are well exposed also near Hoffmans Mill. It seems probable that the more open folds are minor structures on the limbs of the more appressed folds.

METAMORPHISM OF THE CRYSTALLINE SCHISTS OF THE PIEDMONT

The crystalline schists of the eastern and western sequences of the Piedmont area are separated from the Baltimore gneiss by a marked structural and metamorphic unconformity. The term Baltimore gneiss is used in Maryland to include an intensely folded series of granitoid gneiss and injection gneisses. These rocks, with the Hartley augen gneiss which is intrusive in the Baltimore gneiss, form an injection complex which the writers believe represents part of the basement rocks of early pre-Cambrian ("Archean") age. This injection complex underlies all of the Appalachian region and is now exposed in Maryland in uplifts in the Piedmont upland and in the Middletown and Rohrersville anticlines in the core of the Catoctin Mountain-Blue Ridge uplift.

The intrusive rocks of the complex were crystallized during stress and movement, in a deep zone in early pre-Cambrian time. Paleozoic deformation modified the primary structures of the injection complex only locally by the formation of a secondary cleavage which transects the older structures. In certain zones in the Middletown anticline, biotite granite gneiss of early pre-Cambrian age has become a cataclastic muscovite granite gneiss. The schistosity of the gneiss is parallel to the planes in the younger "greenstone" dikes which cut the granite gneiss.

The crystalline schist series that unconformably overlies the Baltimore gneiss and associated rocks of the injection complex has undergone polymetamorphism and intense deformation during Paleozoic orogeny. The Setters formation and the oligoclase-mica schist of the Wissahickon formation are completely crystallized granoblastic rocks of high-rank metamorphism. The oligoclase-mica schist is composed of biotite, oligoclase, and quartz with garnet and, in places, staurolite and kyanite. They are examples of rocks that crystallized in the mesozone, as the term is used by Grübemann and Niggli,[56] who place emphasis on the depth factor in metamorphism. Eskola[57], however, uses the terms "green schist" facies and "amphibolite schist" facies to designate, respectively, metamorphism of lower and higher rank, without implication as to the depth of metamorphism. He designates a metamorphic facies as a group of rocks characterized by a definite set of minerals which, under the conditions of temperature and pressure that obtained during their formation, were in perfect equilibrium with each other. The minerals now present in the oligoclase-mica schist facies of the Wissahickon formation in Maryland belong to the amphibolite-schist facies of metamorphism and show little change in metamorphic conditions throughout their crystallization.

The oligoclase-mica schist has been subjected to pressure subsequent to crystallization, as is shown in the strain shadows in quartz and in the fragmented garnets which have been cemented by secondary quartz. The metamorphism, however, has outlasted the deformation. The Peters Creek formation, which lies northwest of the oligoclase-mica schist facies of the Wissahickon, is a granoblastic mixture of biotite, sericite, and oligoclase. It is finer grained than the oligoclase-mica schist. During post-crystalline movement, the mica was badly crumpled and altered to chlorite. Garnet also was changed to chlorite. These alterations record a change

[56] Grübemann, U., and Niggli, P., Die Gesteinmetamorphose, pp. 397–413, 1924.
[57] Eskola, P., The mineral facies of rocks. Norsk Geol. tidsskr., Vol. 6, pp. 143–194, 1930.

in metamorphic intensity before movement in the area ceased. It is evident that the earlier-formed minerals of high-rank metamorphism were no longer stable under conditions of temperature and pressure that prevailed later in the movement.

The albite-chlorite schist facies of the Wissahickon formation, which lies northwest of the Peters Creek formation, conforms to the "green schist" facies of metamorphism. It is a chlorite-muscovite-quartz schist with albite metacrysts. The crystallization is paracrystalline with the folding. The albites contain a streamline of inclusions that is a residual structure of a former stage of crystallization. The included minerals, biotite and garnet, are of a higher metamorphic rank than the other constituent of the schist. In the albite-chlorite schist in York County, Pa.[58] the albite metacrysts have a border of clear albite around some of the cores with helicitic inclusions, indicating a renewal of crystallization during late stages of the folding. The mica flakes and albite grains are paracrystalline with the folding of the recumbent folds. Their crystallization continued during the shearing out of these folds and the formation of foliation layers. The transverse cleavage, which is the latest structure, tends to shear out the earlier-formed mica layers. Crystallization continued after the development of this cleavage, for coarse porphyroblastic muscovite, chlorite, and chloritoid are not disturbed by the transverse cleavage. The albite-chlorite schist of the northwestern part of the Wissahickon area, in the vicinity of Manchester, Westminster, and Dug Hill Ridge, is finer-grained schist of the "green schist" facies. The foliation is more closely folded and the transverse cleavage is well developed.

The Marburg schist, which lies northwest of the finer-grained albite-chlorite schist of the northwestern part of the area of the Wissahickon formation, is still finer in grain. The Marburg schist is a medium- to fine-grained schist or phyllite of low metamorphic intensity. The folding is close, and the latest structure, a steeply dipping transverse cleavage, has, in part, sheared out the muscovite and chlorite which are paracrystalline with the folding.

The Wakefield marble, which underlies the albite-chlorite schist of the Wissahickon and the volcanic series, is less coarsely crystalline than the Cockeysville marble in the southeastern belt.

The volcanic series is composed of fine-grained crystalline schists and phyllites of low metamorphic rank. The minerals are paracrystalline with the folding. Post-crystalline deformation has produced cataclasis of quartz and streaking out of chlorite and muscovite. This deformation is in response to the development of a closely spaced transverse cleavage.

Summary.—Heat and pressure, produced during folding, have recrystallized and metamorphosed all of the crystalline schist series from the Setters formation upwards. The crystallization was contemporaneous with the folding and outlasted it in the southeastern part of the belt. Retrogressive changes occurred in zones in the Peters Creek formation. The grade of metamorphism and attendant grain sizes decrease from the southeast towards the northwest. The latest structure, which is more pronounced in the northwest part of the belt, is a closely spaced transverse cleavage which has deformed the mineral constituents.

[58] Stose, A. J., and Stose, G. W., Geology of the Hanover-York district, Pennsylvania, op. cit., p. 45, 1944.

In southeastern Carroll County the Sykesville granite intrudes the schists of the high-rank metamorphic belt. These schists show no metamorphic aureole at the granite contact. Though the granite intrusion may have increased metamorphic activity under the operation of increased temperature due to intrusion, there is no direct evidence that such an increase took place. The Sykesville granite has a gneissic foliation. The foliation of the granite and the wall rocks conform to a major structure of the region, the Peach Bottom syncline. The alteration of garnet to chlorite in the Sykesville granite and adjacent schists indicates that the granite has undergone a retrogressive metamorphic change in common with the neighboring schists.

While the metamorphism shows a southeastward maximum, a record of an earlier high-rank metamorphism is preserved in the albite-chlorite schist of the northwestern belt. The volcanic series of this belt contains minerals of the "green schist" facies. It shows a strong mechanical deformation which suggest phyllonitization. The volcanic series contains chlorite, ilmenite, titanite, and iron dust that was derived probably from titaniferous biotite. Ilmenite is altered to leucoxene. This alteration of biotite to chlorite and of ilmenite to leucoxene are retrogressive changes. If the present metamorphic low-rank metamorphism of the schists of the western belt is a product of retrogression, the evidence of such a process has been almost entirely obliterated.

The polymetamorphism of the crystalline schists is characteristic of rocks that have been crystallized in zones of movement; if the schists were affected by hydrothermal metamorphism, its action was of minor importance.

AGE AND RELATIONS OF THE CRYSTALLINE SCHISTS

The Setters formation at the base of the series of crystalline schists is unconformable with the Baltimore gneiss, which is part of the "Archean" basement complex. On the east side of the Frederick Valley, on the western border of the crystalline schists, the Ijamsville phyllite overlies Lower Cambrian Antietam quartzite and Upper Cambrian Frederick limestone. The Ijamsville phyllite, which is part of the volcanic series, is in unconformable relation to the Cambrian rocks. The phyllite and associated rocks are closely folded and have a steep-axis structure which is not developed in the Cambrian rocks; hence the phyllite is separated from them by a structural, as well as a stratigraphic, unconformity. In Pennsylvania the crystalline schists at their northern border overlie Harpers phyllite and Vintage dolomite of Lower Cambrian age and Conestoga limestone of Ordovician (Upper Canadian) age. There, also, the contact cannot be a conformable one. If the discordant contact is produced by sedimentary overlap, the crystalline schists near the contact would be of post-Conestoga age. If the contact on the east side of the Frederick Valley and in Pennsylvania is an overthrust fault, as the writers believe, the relation of the crystalline schists to Paleozoic rocks gives no clue to the age of the schists.

In Sugarloaf Mountain white quartzites and ferruginous quartzites and interbedded slates overlie the Urbana phyllite of the volcanic series. These quartzites have been called Lower Cambrian since the days of J. P. Lesley and G. H. Williams

(1892), but no fossils have been found in them. In a preliminary paper[59] the quartzites on Sugarloaf Mountain were regarded as probably of Lower Cambrian age and their occurrence in a syncline in the volcanic rocks was cited as proof of the pre-Cambrian age of the marble-volcanic series and of the crystalline schists of Carroll and Frederick Counties. In later work in the area the writers found that the lower quartzites in the Sugarloaf Mountain syncline are interbedded with slates that are probably tuffaceous in part, and therefore they conclude that these lower beds are part of the volcanic series, that the Sugarloaf Mountain quartzite is not of proven Lower Cambrian age, and hence that the pre-Cambrian age of the underlying volcanic rocks is not established.

The Cardiff conglomerate and the Peach Bottom slate of Maryland and Pennsylvania overlie the Peters Creek formation, and were designated as pre-Cambrian[60] by the U. S. Geological Survey and Maryland Geological Survey in 1923 because no evidence of unconformity at the base of the Cardiff conglomerate was found. Lesley[61] mentioned that specimens of *Buthotrephis flexuosa* were found in the Peach Bottom slate, but the specimens cannot be located for examination and no other fossils have been obtained from the slate. In a report on York County, Pa.,[62] which includes parts of the area of Peach Bottom slate, Stose and Jonas give their reasons for concluding that the Cardiff conglomerate and Peach Bottom slate are not part of the underlying series of crystalline schists and are probably of Ordovician age.

In Virginia the Arvonia slate,[63] with a conglomerate at the base, overlies the Peters Creek formation with an angular unconformity. This slate contains fossils[64] of late Ordovician (Maysville) age. The Peach Bottom slate occurs in the same syncline as the Arvonia slate. The slates in the two areas are lithologically similar and in both areas are underlain by quartzose conglomerate. The Cardiff conglomerate and Peach Bottom slate therefore are regarded as probably of Ordovician age. The Peters Creek formation which underlies the slates in Virginia, Maryland, and Pennsylvania is therefore pre-Maysville in age.

In earlier work on the crystalline schists of the Piedmont upland, Mathews[65] tentatively correlated the Setters quartzite of Maryland with the Lower Cambrian Chickies quartzite of Pennsylvania and the Cockeysville marble with limestone which overlies the Chickies quartzite and which at that time was called the Shenandoah limestone

[59] Jonas, A. I., Pre-Cambrian rocks of the western Piedmont of Maryland. Geol. Soc. Amer. Bull., vol. 35, pp. 361–363, 1924.

[60] Knopf, E. B., and Jonas, A. I., op. cit., Am. Jour. Sci., vol. 5, pp. 40–62, 1923.

[61] Lesley, J. P., Age and position of the Peach Bottom Slates. Am. Phil. Soc. Proc., vol. 18, pp. 364-369, 1879.

[62] Stose, G. W., and Jonas, Anna I., Geology and Mineral Resources of York County, Pa. Penn. Topog. & Geol. Surv., Bull. C.67, pp. 95–102, 106, 1939.

[63] Brown, C. B., Outline of the Geology and Mineral resources of Goochland County, Virginia. Va. Geol. Surv., Bull. 48, p. 14, 1938.

[64] Darton, N. H., Fossils in the "Archean" rocks of the central Piedmont, Virginia. Am. Jour. Sci., 3d. Ser., vol. 44, pp. 50–52, 1892.

Jonas, A. I., Kyanite in Virginia. Va. Geol. Surv., Bull. 38, p. 25, 1932.

[65] Mathews, E. B., Correlation of Maryland and Pennsylvania Piedmont formations. Geol. Soc. Amer. Bull., vol. 16, pp. 329–346, 1905.

of Cambro-Ordovician age. He made this correlation in part because Bascom[66] believed that the Wissahickon schist, which she then called Ordovician, stratigraphically overlies the Shenandoah limestone on the south side of Chester Valley, Pennsylvania, where the limestone appeared to her to grade upward into the schist. In 1909 Bascom[67] described the Wissahickon gneiss in the Philadelphia region as of pre-Cambrian age.

In 1916 Bliss and Jonas[68] correlated the marble at Doe Run and Avondale with the Shenandoah limestone of Chester Valley and suggested that the contact of the marble with the overlying Wissahickon formation of pre-Cambrian age is an overthrust fault, the Doe Run overthrust. The marble at Doe Run and Avondale resembles the Cockeysville marble in character and stratigraphic position, and overlies quartzite that resembles the Setters quartzite, and the quartzite in Pennsylvania overlies unconformably the Baltimore gneiss.

As a result of later work in Baltimore County, Maryland, E. B. Knopf and Jonas[69] concluded that the Wissahickon formation in Baltimore County is in normal sequence over the Cockeysville marble and that the Setters formation, Cockeysville marble, and Wissahickon formation are part of the Glenarm series[70] and are of pre-Cambrian age. The main reason why those writers assigned the Glenarm series to the pre-Cambrian was that the Glenarm series does not correspond in lithologic character or thickness to the Lower Paleozoic section which lies northwest of the Glenarm series in southeastern Pennsylvania. There the Cambrian and lower Ordovician limestones are several thousand feet thick. The Cockeysville marble is, at most, only 400 feet thick, and the thick argillaceous series containing volcanic flows and tuffs which lie above the Cockeysville are very different in character from formations in the lower Paleozoic section.

In western New England the lower Paleozoic rocks are in two sequences—a western limestone sequence and an eastern argillaceous sequence. The limestone sequence overlies quartzite of Lower Cambrian age, which in turn rests on pre-Cambrian granite gneisses. The rocks in the eastern or Taconic sequence[71] are predominantly shale and graywacke, in places with subordinate beds of sandstone and limestone. Fossils found in the argillaceous sequence show that it ranges from Lower Cambrian to Ordovician in age. It may contain also beds of pre-Cambrian age. . In the Taconic quadrangle, these rocks lie west of the Green Mountains, where they rest in overthrust position on the limestone sequence and are in a mildly metamorphosed condition. In the Hoosac Range, east of the Green Mountains, Hoosac albite schist

[66] Bascom, F., Piedmont district of Pennsylvania. Geol. Soc. Amer. Bull., vol. 16, p. 306, 1905.

[67] Bascom, F., Philadelphia Folio. U. S. Geol. Surv. Geologic Atlas, No. 162, p. 4, 1909.

[68] Bliss, E. F., and Jonas, A. I., Relations of the Wissahickon mica gneiss to the Shenandoah limestone and Octoraro schist of the Doe Run and Avondale region, Chester County, Pennsylvania. U. S. Geol. Surv. Prof. Paper 98-B, pp. 26–27, 1916.

[69] Knopf, E. B., and Jonas, A. I., Geology of the crystalline rocks of Baltimore County, Maryland. Md. Geol. Surv., p. 181, 1929.

[70] Knopf, E. B., and Jonas, A. I., Stratigraphy of the Crystalline schists of Pennsylvania and Maryland. Am. Jour. Sci., 5th ser., vol. 5, pp. 43–49, 1923.

[71] Prindle, L. M., and Knopf, E. B., Geology of the Taconic quadrangle. Am. Jour. Sci., 5th ser., vol. 24, pp. 275–293, 1932.

and overlying Rowe chloritoid schist rest on pre-Cambrian gneisses, the Mount Holly and Stamford gneisses. In the Taconic Mountains green and purple chloritoid slate and albite phyllite in places merge with green and purple sericitic and chloritic slates of Lower Cambrian age and the phyllites are so similar to the Hoosac and Rowe schists as to suggest a relationship. It is not established whether the contact of the Hoosac and Rowe schists on pre-Cambrian gneisses is a depositional one or an overthrust. Prindle, the senior author of the report referred to above, believes that the Hoosac and Rowe schists are of Lower Cambrian age and rest with a sedimentary contact on the pre-Cambrian Mount Holly and Stamford gneisses of Hoosac Mountain. The junior author of that report (E. B. Knopf) accepts this conclusion with reservation.

The crystalline schists which overlie the Cockeysville marble resemble in lithologic character the Hoosac and Rowe schists and the Taconic sequence. In many places in Baltimore County the Wissahickon formation overlaps the Cockeysville marble onto the Setters formation and in places onto the Baltimore gneiss. Over wide areas in southern Virginia and in North Carolina the Wissahickon formation rests directly on the injection complex of early pre-Cambrian age.

The writers of this report therefore suggest that the Setters quartzite and Cockeysville marble may be Lower Cambrian in age and may represent the lowermost part of the limestone sequence characteristic of the Great Valley, and that the overlying crystalline schists may be equivalent in part to the argillaceous Taconic sequence of New England. In other words, the Setters quartzite may represent the Lower Cambrian Chickies quartzite and equivalent quartzose formations; the Cockeysville marble may represent the lowermost Paleozoic carbonate rocks, chiefly the Lower Cambrian Vintage or Tomstown dolomite; the overlying crystalline schist may be an eastern argillaceous sequence equivalent to the Taconic sequence of New England, which is known to be Lower Cambrian to Ordovician in age and may be in part of pre-Cambrian age.

In New England the Taconic sequence belongs to a different basin of sedimentation from that in which the carbonate sequence was deposited. If the same conditions of sedimentation obtained in Pennsylvania and Maryland, the Wissahickon formation and associated rocks of the crystalline schist series have come to lie on the Cockeysville marble, Setters formation, and Baltimore gneiss in the Maryland region by overthrusting which took place in post-Cambrian time.

TRIASSIC SYSTEM

GENERAL DESCRIPTION

A belt of red sandstone and shale of Triassic age crosses Maryland in Frederick and Carroll Counties. The Triassic rocks, known as the Newark group, are a part of a long belt which crosses Pennsylvania, extends into and across Maryland, and continues southward into Virginia. At the Maryland-Pennsylvania State line the Newark group is 14 miles wide. It narrows southwestward to the vicinity of Frederick, where it is absent for a distance of 2 miles and is separated from a southern belt by limestones of the Frederick Valley. The southern area is a belt about 3 miles wide, which extends from a point 1 mile west of Frederick to Potomac River. The

Triassic rocks lie east of Catoctin Mountain and west of the crystalline schists and limestones of the Piedmont upland.

In southern Pennsylvania the Newark group is divided into two units, the New Oxford formation at the base and the Gettysburg shale above. The two formations extend from Pennsylvania into Carroll and Frederick Counties. The beds of both formations dip gently northwest. They are cut off on the west by the Triassic border fault.

New Oxford Formation

Distribution.—The New Oxford formation lies on the southeast side of the area of Newark rocks. From Potomac River northward to U. S. Highway 40, at a point 2 miles west of Frederick, the New Oxford formation forms a belt 2 to 3 miles wide. There it lies directly east of the Triassic border fault and is not overlain by the Gettysburg shale. A small wedge shaped area of the New Oxford formation, down-faulted on the west side, is on the east side of the Frederick Valley at the mouth of Monocacy River. This area extends south into Montgomery County, Maryland, and into Virginia, where the Newark rocks widen considerably.

Northwest of Frederick the New Oxford formation is absent for a short distance but begins again at a point 2 miles northwest of Frederick and widens northeastward. In the vicinity of Taneytown the formation is 8 miles wide. On the west side, from a point near Creagerstown and northeastward, the rocks of the formation dip west under the Gettysburg shale. In the region south of Frederick the beds strike north. Four miles northeast of Frederick the strike changes to N. 40° E. From Potomac River northeastward to a point 1 mile east of New Midway, the New Oxford formation overlies the Frederick and Grove limestones. Northeast of that point it overlies the crystalline schists of the Piedmont upland, and in the vicinity of the Maryland-Pennsylvania State line it rests on Antietam quartzite. North of Tyrone a down-faulted outlying mass of the New Oxford formation over 2 miles long lies in the crystalline schists 1½ miles east of the main area.

Character and Thickness.—The New Oxford formation is composed chiefly of red to purplish sandstone and shale, with beds of light-gray to greenish-yellow arkosic sandstones. The arkosic beds and the red sandstones commonly contain sedimentary mica. A conglomerate of variable composition is present at the base of the formation nearly everywhere in the two counties. Its distribution is shown on the Frederick County geologic map. South of U. S. Highway 40 and for a distance of 1 mile northward in the area northwest of Frederick, the conglomerate contains rounded limestone pebbles. Farther north the conglomerate becomes quartzose.

From Potomac River northward to U. S. Highway 40, the limestone conglomerate forms a continuous belt, one half to one mile wide, which lies east of the Triassic border fault and on the west side of the sandstones of the New Oxford formation. East of Braddock Heights a narrow outcrop of the conglomerate curves around the north side of the sandstone area, turns south, and extends along the east side of the area to a point just north of Doubs, where it appears to end. To the south it is present again in places from the vicinity of Pleasant View to Potomac River.

The limestone conglomerate does not show bedding but the dips in the overlying

New Oxford formation are 25° NW. on the east side and 15° NW. on the west side. The lower dip on the west side may account for the greater width of the western belt of the conglomerate. In the western belt beds of conglomerate are separated by red calcareous shale. The shale commonly weathers to soil, whereas the more resistant limestone conglomerate in many places forms large ledges and boulders 8 to 10 feet high. The conglomerate exposed just south of U. S. Highway 40 appears to be 20 feet thick. Near Potomac River, east of Point of Rocks, the conglomerate crops out in cuts on the Baltimore and Ohio Railroad and also at many places to the northeast.

North of U. S. Highway 40, the limestone conglomerate is at the base of the formation for a distance of 1 mile near Carroll Creek, and caps a small outlying hill 1 mile south of Indian Springs. The hill is cut through by the Frederick Railroad exposing limestone conglomerate overlying gray siliceous Paleozoic dolomite. A small mass of limestone conglomerate overlies Paleozoic limestone ½ mile northwest of Creagerstown station on this railroad. The limestone in a quarry at this place is brecciated and cemented by iron oxide along a northwest-trending cross fault.

The limestone conglomerate is composed of coarse and fine pebbles of white and gray Paleozoic limestone and scattered quartz pebbles enclosed in a matrix of fine gray to red limestone containing grains of quartz. Some of the limestone of the pebbles resembles the lower Paleozoic limestones on which the conglomerate rests, and this fact indicates a nearby source for the pebbles. Because the matrix is in part siliceous, the conglomerate dissolves less readily and forms a thinner soil than do the Paleozoic limestones. The limestone conglomerate can be sawed and polished, and is used as ornamental stone, known as Potomac marble. The marble is unique in that the gray to white and black limestone pebbles give it a coarsely spotted or blotched appearance, and for this reason has been called "Calico" marble. Large blocks of this marble were quarried east of Point of Rocks and made into polished columns for use in the interior of the Federal Capitol at Washington, D. C. The columns are about 4 feet across and 20 to 25 feet high.

The quartzose conglomerate in the basal part of the New Oxford formation is composed of round or oval pebbles and cobbles of quartz in a matrix of red sand. The conglomerate is interbedded with coarse-grained arkosic sandstones. Southwest of Monocacy River, where it is exposed northwest of Devilbiss Bridge near the southwest end of the quartzose conglomerate, it is not over 20 feet thick. Northeast of Monocacy River, from the vicinity of Chestnut Hill northeastward, the conglomerate thickens and forms low hills that rise 30 to 50 feet above the adjoining surface underlain by limestone and schists. The conglomerate in Chestnut Hill is made up of pebble beds 4 feet thick in red arkosic sandstone. The quartz cobbles are 6 to 9 inches in diameter. Conglomerate with still larger quartz cobbles is exposed in a railroad cut just northeast of Ladiesburg. The conglomerate dips 15° NW., and lies on Ijamsville phyllite (Pl. 14B). From a point near Weishaars Mill to a point 1 mile north of Arters Mill, the conglomerate strikes N. 30° E. and dips about 30° NW., and forms a continuous ridge. From a point 1 mile north of Arters Mill to the Maryland-Pennsylvania State line, three cross faults offset the base of the New Oxford formation.

In the outlier of the New Oxford formation north of Tyrone, basal quartzose conglomerate on the east side overlies Marburg schist and dips northwest under red sandstone. On the northwest side the New Oxford formation is down-dropped on a normal fault, and on the south side it is cut off across the strike by a transverse fault.

The New Oxford formation is intruded by dikes of Triassic diabase in the vicinity of Appolds, Rocky Ridge, and southward to LeGore. Near the contact the red shale and sandstone are altered to a blue or gray color.

North of U. S. Highway 40 the beds of the New Oxford formation dip uniformly northwestward at angles of 15 to 25°. The thickness of the formation computed at the narrow part of its outcrop south of Creagerstown, where there is no repetition of beds by faulting, is about 4500 feet. This thickness is comparable to the estimated thickness of 6000 feet in the adjacent part of Pennsylvania.

Age.—The New Oxford formation was named from the town of New Oxford, Pennsylvania. The formation overlies the Paleozoic limestones and quartzites exposed in the Frederick Valley, and its basal conglomerate overlaps all of these Paleozoic formations. Limestone exposed at or beneath the edge of the Triassic rocks is stained red at many places. The Triassic rocks are not folded, except locally near faults, whereas the underlying Paleozoic rocks were closely folded and were eroded before the Newark rocks were deposited. They are therefore of post-Paleozoic age since the Paleozoic rocks were folded in the closing stages of the Paleozoic.

The few fossils found in the New Oxford formation are of continental type. Small fragments of carbonized plant remains and twigs and silicified wood have been collected from arkosic beds of the formation in southern Pennsylvania. The fossil wood has been identified by E. T. Wherry as a conifer—*Araucarioxylon vanartsdaleni.* Reptilian bones and teeth of a crocodile have also been found in these beds in Pennsylvania. A small phyllopod shell, *Estheria ovata* Lea, has been collected by the writers near Farmers and New Oxford, Pennsylvania. These fossils suggest an Upper Triassic age, and their character indicates terrestrial and in part swampy conditions.

Gettysburg Shale

Distribution.—The Gettysburg shale conformably overlies the New Oxford formation, occupies the northwestern part of the belt of Newark rocks, and lies east of the Triassic border fault. At the southwest end near Creagerstown, the base of the formation extends northeastward to a point just west of Harney at the Maryland-Pennsylvania State line. North of Rocky Ridge the base of the formation has a deep reentrant where it is offset by a northwest-trending fault. The fault extends northwestward to Mount St. Marys, and northwest of that place cuts off the northeast end of Catoctin Mountain. East of the fault, in the vicinity of Emmitsburg, the formation is over 6 miles wide.

Character and Thickness.—The Gettysburg shale is composed of red shale and soft red sandstone. At Motters it contains red and green fissile shale. The base is somewhat arbitrarily determined at the horizon where light-colored sandstones and arkoses, characteristic of the New Oxford formation, cease to occur and the rocks have a uniformly red color. North of Emmitsburg, the Gettysburg shale is intruded by two sills of diabase. Two diabase dikes extend south into the shale from the eastern sill. The dikes are paralleled by shorter dikes not connected with the sill. The red shale on the lower border of the sill is altered to a dense bluish-black porcelanite for a width of $\frac{1}{8}$ to $\frac{1}{2}$ mile. It grades downward through a narrow zone of purple shale into the normal red shale of the Gettysburg. In places shale at the border of the diabase dikes also is baked blue.

East of Thurmont, where the beds dip from 10° to 20° W., the Gettysburg shale is estimated to be less than 5000 feet thick. In the wider area near Emmitsburg, the formation probably is much thicker. It is assumed that near Thurmont, adjacent to the border fault, higher beds were deposited and have been eroded, and hence the original thickness may have been greater than that of the beds now exposed in Maryland. In southern Pennsylvania, where higher beds are present, the Gettysburg shale is estimated to be 9000 feet thick.

Age.—The Gettysburg shale was named from Gettysburg, Adams County, Pennsylvania, and extends continuously northeastward from that county across York County into Lancaster County, Pennsylvania. In Lancaster County small shells of a phyllopod crustacean, *Estheria ovata* Lea, were collected from the formation. Fossil footprints of dinosaurs have been found in the sandstone quarried near Emmitsburg, and similar footprints have been collected in the rocks of southern Pennsylvania. Plant remains found near Goldsboro, York County, Pennsylvania, have been studied and 31 species have been distinguished.[72] These plants include ferns, equisetums, cycads, ginkos, conifers, and grasses. The fossils indicate Upper Triassic age.

Source of the Triassic Sediments

The Triassic sediments were deposited in a long narrow basin floored by Paleozoic limestone and crystalline rocks. The basin lay west of a highland of crystalline rocks which were subjected to deep weathering. Quartz, feldspar, mica, and red mud, derived from these deeply weathered rocks, were washed into the basin. The early deposits were limited to the southeast side of the basin and later deposits to the northwest side. The lithologic character of the basal conglomerate reflects the character of the floor. Where the New Oxford formation rests on crystalline rocks, the basal conglomerate is commonly quartzose. Where it lies on limestone, the conglomerate contains limestone pebbles. In Pennsylvania the conglomerate on the western side, along the border fault, was derived from uplifted Paleozoic rocks to the west during the closing stages of Gettysburg deposition. The sinking of the basin during Triassic time was in part accomplished by faulting of the floor near the western margin. In Adams and York Counties,[73] Pennsylvania, the latest Triassic deposits overlap the border fault onto the limestone floor beyond; also, just before the end of Triassic deposition, the northwest margin of the basin was strongly uplifted, and large quantities of coarse, poorly assorted material were deposited along

[72] Stose, G. W., and Jonas, A. I., op. cit. Pa. Geol. Surv., 4th Series, Bull. C.67, pp. 120, pls. 22, 23, 1939.

[73] Stose, G. W., Geology and Mineral resources of Adams County, Pennsylvania. Topo. and Geol. Survey of Pennsylvania, Bull. C.1, p. 92, 1932.

Stose, G. W., and Jonas, A. I., op. cit. Pa. Geol. Surv., 4th Ser., Bull. C.67, p. 118, 1939.

the west border as fanglomerate. In southern Frederick County the limestone conglomerate that is just east of the border fault may have been so derived. In the northern part of the county, north of Catoctin, the west edge of the Gettysburg shale lies just east of the Frederick limestone for a distance of 5 miles. Except at Roddy, the contact is concealed by a thick cover of Quaternary gravel. Near Roddy, limestone conglomerate in the Gettysburg shale is exposed at the contact with the Frederick limestone. The writers found no evidence of a fault east of the limestone, but because elsewhere in Frederick County the upper beds of the Gettysburg shale have not been found to overlap on the limestone floor, it is possible that the Triassic rocks are down-faulted against the limestone, as is suggested in figure 18. The Frederick limestone in the small area east of the border fault, south of Mount St. Marys, may also be bounded by normal faults not shown on the geologic map.

QUATERNARY SYSTEM

ALLUVIAL CONES

Alluvial cones have been deposited on benches at the mouths of gorges and ravines in the east slope of Catoctin Mountain. The cones are composed of large and small boulders, pebbles, and sand derived from the quartzite and slate in the mountains and brought down by streams. They were deposited on the valley floor east of the mountain before the floor was eroded to its present level and stood at about 500 feet altitude. The gravels have since been spread to lower levels by later erosion and transportation. The alluvial cones were deposited in early Pleistocene or possibly latest Tertiary time.

The largest alluvial cone, composed chiefly of quartzite cobble, is at the mouth of Hunting Creek and spreads eastward from the foot of the mountain for a distance of 3 miles to Graceham. The town of Thurmont is located on the summit of the cone. Other large cones are at the mouths of Little Hunting, Fishing, and Little Tuscarora Creeks and the North Branch of Owens Creek. All of the cones were later trenched by the streams that formed them.

TERRACE GRAVELS

Terrace gravels have been mapped bordering Potomac and Monocacy Rivers. The gravels bordering Potomac River are at two levels, the higher terrace at 420–440 feet altitude, and the lower one at about 300 feet. The gravel-covered terraces along Monocacy River from Devilbiss Bridge to Frederick are about 300 feet in altitude. These gravels therefore were deposited when the channels of the streams were at these levels, probably during stages of the glacial epoch.

ALLUVIUM

Alluvium is present on flood plains of all the larger streams in the area, but has been mapped only along Potomac River because alluvium along the other streams is scanty. In the rocky gorge through the Appalachian Mountains the flood plain of the river is narrow, but it widens southeast of Point of Rocks. In this part of the river channel alluvium covers wide stretches of bottom land north of the river and on large islands in the river. The fine sand with streaks of gravel of the alluvium

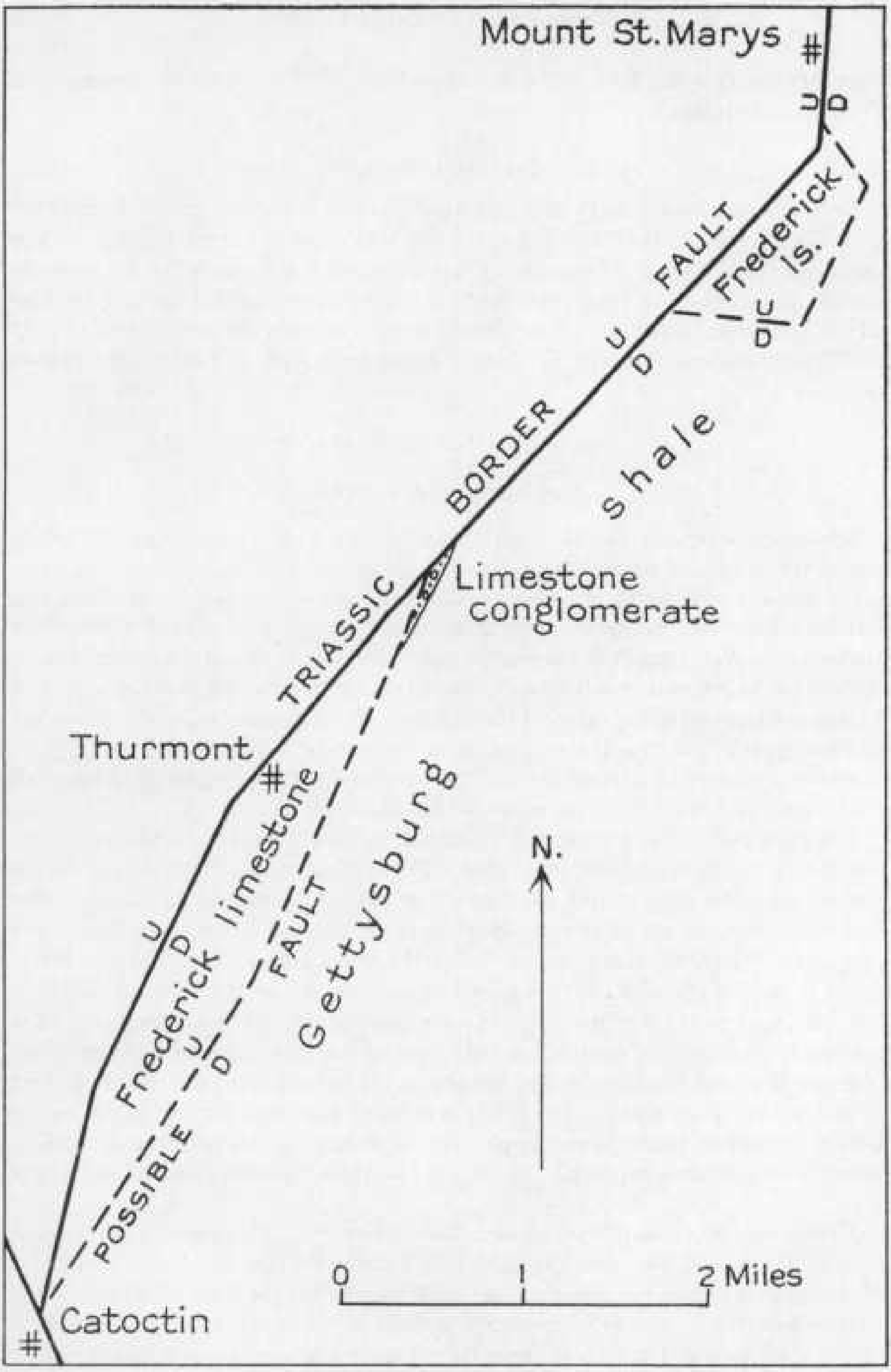

FIG. 18. Map showing Triassic border fault and possible branch faults in vicinity of Thurmont. Shows possible branch faults between Frederick limestone and Gettysburg shale east of Thurmont and south of Mount St. Marys.

furnishes excellent soil for farming, but these bottom lands are subject to occasional flooding and erosion.

INTRUSIVE ROCKS

General Description.—Serpentine, metagabbro, and Sykesville granite intrude the crystalline schists of the Piedmont upland in southeastern Carroll County. Their exact age is not known. Pegmatite of late Paleozoic age intrudes the Cockeysville marble, the schists, and Sykesville granite in southeastern Carroll County. Diabase sills of Triassic age occur in the Triassic sedimentary rocks in northern Carroll County and Triassic diabase dikes cut the Triassic sedimentary rocks and older rocks in both counties.

PRE-CARBONIFEROUS INTRUSIVES

Serpentine and Metagabbro

Serpentine occurs in Carroll County as a sill-like body which trends N. 40° E. across the southeast corner of the county. It enters from Baltimore County at a point about a mile south of where the Liberty road crosses the North Branch of Patapsco River and extends southwest across the county to a point ¾ mile west of Henryton on West Branch of Patapsco River. The rock is pyroxenite altered almost completely to serpentine. It is well exposed on the North and West Branches of Patapsco River and in the valley of Piney Run. The serpentine mass has an average width of ½ mile, but near the south edge of the county it narrows to about ⅛ mile. It forms a ridge characterized by thin soil covered by a scanty growth of pine and cedar, and the surface is strewn with boulders of serpentine.

The main part of the intrusion is a massive dark-green pyroxenite altered almost completely to yellowish-green serpentine. The borders of the intrusive body at the contact with the country rock are steatite or talc schist and chlorite schist. The talc schist is made up of greenish-gray fibers of talc and has a soapy feel. The pyroxenite is intruded along the contact of the Wissahickon schist with the Peters Creek formation and dips with the country rock. On the southeast side it dips 30°–35° NW., and on the northwest side the dip is steeper, in the same direction. The talc schist was formerly quarried on both sides of the serpentine mass in the valley of Piney Run, and in a large quarry located on the top of a hill ½ mile north of West Branch of Patapsco River. The talc was shipped unground for use in the manufacture of graphite products and soap. The serpentine extends northeast into Baltimore County where it expands in width and forms the "Soldiers Delight" serpentine area.

Metagabbro occurs as dikes in eastern Carroll County. The largest dikes are near North Branch, and they pass eastward into Baltimore County. A thin small dike of metagabbro crosses the Wissahickon formation south of the serpentine body ½ mile west of Henryton. The other metagabbro dikes are in the Peters Creek formation. One of them extends from a point near Haight southwestward about 4 miles to Piney Run. The longest dike of metagabbro, known as the Finksburg dike, extends across the county from near Glen Falls Station on the North Branch of Patapsco River southwestward to the West Branch, 1 mile west of Sykesville, and has a known length of 11 miles.

The metagabbro is a greenish-black foliated rock composed of sparkling hornblende, spotted with white opaque feldspar. In thin section the feldspar is seen to be plagioclase which has altered to epidote, zoisite, and a more sodic plagioclase. Hornblende is green uralite, secondary to pyroxenite. Quartz, magnetite, and apatite are accessory constituents. South of Eldersburg the dike is formed of serpentine and talc schist. Where it is exposed on State Highway 32, south of Morgan Run, the dike is 12 feet wide, divided into two layers by 3 feet of mica schist. The copper deposits of eastern Carroll County are located along this dike, but are not genetically related to the intrusion of the metagabbro.

The metagabbro is intruded along the bedding of the Peters Creek formation, and has been deformed with the country rock and altered to metagabbro. West of Sykesville it appears to cut the Sykesville granite, because masses of metagabbro crop out within the granite area. In Howard County, however, the Sykesville granite includes abundant blocks of metagabbro and hornblende gneiss and the granite was evidently intruded later than these basic rocks.

Sykesville Granite

The Sykesville granite occurs in two areas in southeastern Carroll County. The northeastern area lies west of North Branch of Patapsco River. Its north end is about east of Louisville, and it extends southward about 5 miles with an irregular width, averaging about a mile. North of Oakland a branch of the granite extends northeastward into Baltimore County for a short distance. The western area of granite lies south of Eldersburg, extends to the West Branch of Patapsco River where it is 4 miles wide, and continues southward.

In Carroll County the granite is well exposed in rock cuts of the Baltimore and Ohio Railroad on West Branch of Patapsco River. It crops out also in the valley of Piney Run, southeast of Springfield Hospital. On the upland the granite has weathered to a deep soil, which sparkles with mica and contains much vein quartz and rounded boulders of granite, with few rock exposures. The granite was formerly extensively quarried. One of the largest of the old quarries was the Weller quarry, north of the Baltimore and Ohio Railroad and a mile east of Sykesville. The rock possesses horizontal sheeting and two sets of vertical joints which aid in quarrying. It furnished building blocks for houses, foundations, general construction, and paving blocks.

The rock is a gray to dark greenish-gray biotite-quartz monzonite, with a pronounced gneissic structure produced by the parallel arrangement of the biotite. It varies in grain from fine to coarse and is porphyritic in places. In many places it contains chloritized garnets. Under the microscope the rock shows quartz, orthoclase, oligoclase, and biotite and muscovite in bands and radiating clusters. Orthoclase and plagioclase occur in about equal amounts, hence the name monzonite. The plagioclase, which is oligoclase, has fine twinning and is clouded by alteration to sericite. Zonal structure is not uncommon. Biotite, which contains inclusions of apatite, occurs in clusters with epidote and secondary chlorite, and forms the foliation layers. Accessory minerals are apatite, garnet, zircon, titanite, magnetite, and tourmaline. Allanite, which is common in the granites that occur near Woodstock and at Ellicott City, in Baltimore County, was not found in the Sykesville granite. The granite is cataclastic; quartz has undulatory extinction; feldspar is sericitized and granulated on the borders.

The intrusive relation of the Sykesville granite to the Peters Creek formation is well shown at many places along the contact. The bordering country rock for some distance from the massive granite contains stringers and lenses of granite which have been twisted and kneaded with the sedimentary rock. The granite has penetrated the Peters Creek formation in the form of lit-par-lit injection and in stringers and dikes. Near the contact the granite contains inclusions of country rock, both large and small, the largest observed being 6 feet across. The inclusions are garnetiferous biotite schist and quartzite. The contact rock contains abundant large garnets which are chloritized in many places. Knots of quartz up to $1\frac{1}{2}$ inches in diameter are abundant in the granite near the contact. The quartz knots are elongated bodies that resemble pebbles. In the Weller quarry, Keyes[74] reports that the granite contains inclusions of limestone, soapstone, pyroxenite, and mica schist. The quarry face is now weathered and only inclusions of mica schist are evident.

The following analysis of the Sykesville granite, made by H. F. Hillebrand of the U. S. Geological Survey, is given, together with an analysis of the Woodstock granite of Baltimore County and a white granite from Brookville, Montgomery County. The Woodstock granite contains more lime than the Sykesville, which constituent is probably in the form of epidote. From the recalculation of the norm of the Sykesville granite, orthoclase is 46 per cent of the feldspar and the plagioclase 54 per cent.

Analyses of Sykesville granite and other granites from near-by areas

	I	II	III
SiO_2	71.45	71.79	74.87
Al_2O_3	14.36	15.00	14.27
Fe_2O_3	2.07	.77	—
FeO	2.78	1.12	.51
MgO	1.17	.51	.16
CaO	1.58	2.50	.48
Na_2O	1.95	3.09	3.06
K_2O	3.28	4.75	5.36
H_2O^+			.26
H_2O^-			.66
TiO_2			.05
P_2O_5			.21
Li_2O	tr	tr	
N_2O	1.30	.64	
	99.94	100.17	99.89

I.—Quartz monzonite, Sykesville, Carroll County, Maryland. Analyst, W. F. Hillebrand. Williams, G. H., U. S. Geol. Survey, 15th Ann. Rept., p. 672, 1895.

[74] Keyes, C. R., Origin and relations of the central Maryland granites. U. S. Geol. Survey 15th Ann. Rept., p. 726, 1895.

II.—Biotite granite, Woodstock, Baltimore County, Maryland. Analyst, W. F. Hillebrand. Idem.

III.—White granite, Brookville, Montgomery County, Maryland. Analyst, W. F. Hillebrand. Idem.

Mineral Composition of the Norm of Sykesville Quartz Monzonite

Quartz	40.9
Orthoclase	19.5
Albite	16.2
Anorthoclase	8.1
Corundum	6.0
Hypersthene	6.3
Magnetite	3.0
	100.0

Pegmatite and aplite are associated with the Sykesville granite west of Sykesville and near Oakland, but are not genetically related to it. West of Sykesville, white sericitic aplite about 50 feet wide is exposed in mica schist in cuts on the Baltimore and Ohio Railroad. The Sykesville granite intrudes both the schist and aplite, which are folded together, and the aplite is evidently older than the granite. Muscovite pegmatite which cuts the Sykesville granite in the vicinity of Oakland, is undeformed and younger than the Sykesville granite.

AGE OF THE SERPENTINE, METAGABBRO, AND SYKESVILLE GRANITE

The serpentine and metagabbro have been deformed since their intrusion. The Sykesville granite has a cataclastic texture and a pronounced gneissic foliation. In Howard and Montgomery Counties the injection zone at the border of the granite has a steep-axis structure[75] that is common to the Peters Creek formation into which the granite is intruded. It is concluded that the serpentine, metagabbro, and Sykesville granite were intruded into the Wissahickon and Peters Creek formations before regional folding and were deformed with those formations. The Wissahickon and Peters Creek formations may be Lower Cambrian and Ordovician in age and may be in part of pre-Cambrian age. In the discussion of the structure of the crystalline schists of the Piedmont upland, the writers state their reasons for believing that the regional folding was of late Paleozoic age. The intrusives, therefore, are older than that orogeny and younger than the Wissahickon and Peters Creek formations which they intrude.

LATE PALEOZOIC INTRUSIVES

Muscovite Pegmatite

Muscovite pegmatite intrudes the rocks in southeastern Carroll County in the vicinity of Henryton and Oakland. Near Henryton two parallel intrusions of pegmatite cross the county in a N. 50° E. direction. The southeasterly body intrudes the Cockeysville marble and extends into the overlying Wissahickon formation. The average width of the dike is 50 feet. The pegmatite is well exposed in a quarry

[75] Jonas, A. I., Tectonic studies in the crystalline schists of southeastern Pennsylvania and Maryland. Amer. Jour. Sci., vol. 34, pp. 383–384, 1937.

north of Marriottsville, where it was formerly mined for feldspar. There, the pegmatite intrudes marble and dips with its bedding 45° NW. The northwesterly body is in Wissahickon formation and extends from the railroad tunnel at Henryton northeastward across the county. The dike is 100 to 150 feet wide and dips steeply northwest.

The pegmatite near Oakland extends from the Carroll-Baltimore County line southwestward for 1½ miles. It injects the Peters Creek formation and the Sykesville granite. It is exposed in an old quarry on the west bank of the North Branch of Patapsco River near Oakland. Fine-grained biotite gneiss of the Peters Creek formation has been shattered and thoroughly permeated with white muscovite granite pegmatite which cuts across the foliation of the gneiss and penetrates also along its foliation. The pegmatite is composed of microcline, quartz, and pale-green muscovite. In places it contains garnet. Small muscovite pegmatite bodies occur also northwest of Oakland on Morgan Run, 1½ miles east of Eldersburg, and 1 mile southeast of Sykesville.

Quartz veins cut the Peters Creek formation and the Sykesville granite in the vicinity of the muscovite pegmatite bodies. The largest of these veins crops out near Morgan Run, ½ mile west of North Branch of Patapsco River. In a quarry formerly worked for flint, this vein is 100 feet long and 30 to 40 feet wide. One mile north of Marriottsville, mica pegmatite contains a mass of quartz large enough to have been mined for flint. These quartz veins appear to be quartzose facies of the muscovite pegmatite.

The muscovite pegmatite is not deformed and therefore is later than the folding and deformation of the rocks which it intrudes. On the map of Carroll County it was considered pre-Cambrian in age, but the writers now believe it is probably of late Paleozoic age and a satellite intrusion of the Woodstock granite, which also is believed to be of late Paleozoic age. Overbeck[76] reports that in the Patapsco mine pegmatite cuts the copper deposits. It is probable that the muscovite pegmatite and the mineral veins are closely related in origin and time of intrusion.

TRIASSIC INTRUSIVES

Diabase

Distribution.—Many diabase dikes cut the Triassic and pre-Triassic rocks of Frederick and Carroll Counties, and two diabase sills intrusive in the Triassic sedimentary rocks extend into northern Frederick County north of Emmitsburg. The eastern sill, which lies northeast of Emmitsburg, is the south end of a thick plate, called the Gettysburg sill in Adams County, Pennsylvania. The western sill, northwest of Emmitsburg, is the south end of a thinner curving plate of diabase which also enters Frederick County from Pennsylvania (Fig. 19). The molten diabase entered the sedimentary rocks along their bedding planes, and the beds southeast of the sill dip 35° NW. under it, and those northwest of it overlie it.

In Frederick County three narrow dikes join the south side of the Gettysburg sill and are apparently feeders which connected the sheet-like body with deep-seated

[76] Overbeck, R. M., A metallographic study of the copper ores of Carroll County, Maryland. Econ. Geol., vol. 11, no. 2, p. 151, 1916.

sources of the liquid magma. The two westerly of these dikes join the southwest end of the sill and one of them crosses State Highway 32 one mile east of Emmitsburg. It is the longest and largest dike in this part of the State and can be traced by outcrops and lines of residual diabase boulders entirely across Frederick County into

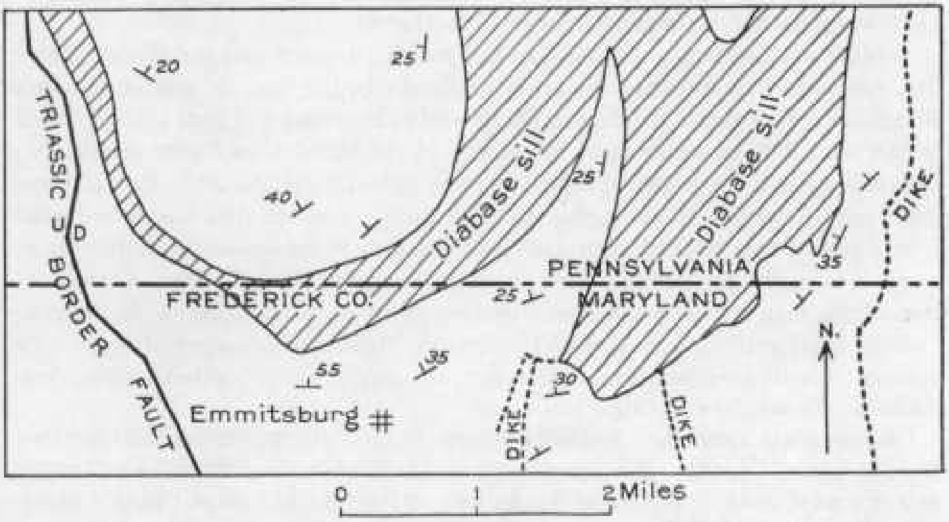

FIG. 19. Map of diabase sills in Gettysburg shale at north edge of Frederick County near Emmittsburg and in adjacent part of Pennsylvania. Shows dip and curving strike of beds parallel to the sills.

Montgomery County, a distance of 35 miles. In the northern part, the dike strikes almost due south. One half mile east of Rocky Ridge the dike is offset, en echelon, about ½ mile, but continues its southerly course. The dike evidently follows parallel joint fractures that were produced in the rocks during the late Triassic deformation and faulting. The joints are more-or-less parallel to the Triassic border fault. Elsewhere, as at Appolds and northeast of Motters, the dike bends sharply between north-trending portions of the dike, and is continuous from one joint fracture to a parallel fracture. East of Appolds, where the dike swells to ½ mile in width, it makes a prominent ridge above the upland surface. East of Rocky Ridge the dike is exposed in the railroad cut, where it is 200 feet wide. The diabase at the center of the dike is coarser grained than at the borders. The dike is vertical and the shale and sandstone at the borders are baked and altered. East of Walkersville, a parallel dike lies to the west of the main dike; and south of U. S. Highway 40, parallel dikes lie on both sides of the main dike. The dike passes out of the Triassic sedimentary rocks at LeGore, but continues southward with the same general trend across the Paleozoic limestones and quartzite of the Frederick Valley. At Bartonsville and farther south it cuts the crystalline rocks of the Piedmont upland in a course a little west of south. The dike enters the Triassic sedimentary rocks again near Monocacy River before it passes into Montgomery County.

The eastern dike that joins the south end of the sill northeast of Emmitsburg also trends due south and swells to greater size south of Toms Creek Church, where it forms a narrow ridge. This dike ends within the Triassic sedimentary rocks at Double Pipe Creek. Another dike crosses State Highway 32 two miles east of Emmitsburg, passes east of the Gettysburg sill in Frederick County, and ends in the Triassic sedimentary rocks. It is the south end of a large dike that extends 10 miles northward into Adams County, Pennsylvania, where it cuts diagonally across the Gettysburg sill and is therefore younger than that sill.

Another south-trending diabase dike in Frederick County cuts the Harpers phyllite, Antietam quartzite, and Tomstown dolomite in the foothills east of Catoctin Mountain. It begins at the diagonal fault west of Braddock and ends at the Triassic border fault 2 miles southeast of Jefferson. In the Middletown Valley several diabase dikes cut the injection complex and the Catoctin metabasalt. Two of these dikes near Knoxville trend slightly west of south. Another dike has been traced from a point ½ mile east of Burkittsville northwesterly to the foot of South Mountain, where it is lost in the debris-covered slopes of the mountain. However, a continuation of this dike trends in the same direction in the Paleozoic rocks of Washington County northwest of Lambs Knoll on South Mountain. Another diabase dike cutting Catoctin metabasalt and the injection complex trends southeast from Reno School at the east foot of South Mountain.

Diabase dikes cross the crystalline schists in the eastern, central, and western parts of Carroll County. Trends of the individual dikes range from due south to 10° east or west of south. Two dikes, 6 miles long, parallel the Baltimore-Carroll County line, passing through Roller and Alesia. They extend northward into York County, Pennsylvania. Another dike extends south from near Shades School, passes west of Westminster, and ends 8 miles south of Westminster. A diabase dike enters Carroll County from Pennsylvania northwest of Pleasant Grove School, and extends southward to the vicinity of Hahns Mill. A larger parallel dike extends from Silver Run southward through Frizzelburg, Wakefield Valley, and Dennings, and crosses Parrs Ridge east of West Falls. The outcrops of these dikes are discontinuous trails of boulders, often reddish-yellow in color because of a weathered crust of iron oxide. The most pronounced outcrop occurs in the Wakefield Valley where the diabase forms a ridge a mile long rising 20 feet above the valley surface.

Character.—The diabase of the sills is coarser grained than that of the dikes. It has a granitic or diabasic texture, but is finer grained at its borders, where the molten magma was chilled by contact with the country rock. In rocks having a diabasic texture, elongated laths of plagioclase, variable in orientation, are enclosed in a matrix of pyroxene and other minerals, forming a typical felted or matted texture. As stated by Lewis,[77] the most abundant constituents of the diabase are greenish-black pyroxene and white or grayish plagioclase. The pyroxene commonly preponderates. Accessory minerals are magnetite and apatite, with minor amounts of quartz, orthoclase, biotite, and titanite. Some of the darker diabase contains hypersthene and olivine, and in places epidote is abundant.

Diabase of the dikes in Frederick and Carroll Counties is greenish-gray, medium-to fine-grained crystalline rock in which green feldspar sparkles in a dark groundmass

[77] Lewis, Volney, Fairfield-Gettysburg folio. U. S. Geol. Surv. Geologic Atlas, no. 225, p. 13, 1929.

of augite. Some of the finer-grained rock is nearly black. In thin section the feldspar is seen to be automorphic laths of labradorite which are usually fresh. Interstitial augite forms the groundmass. Secondary constituents are hornblende and chlorite, and accessory minerals are apatite and magnetite. An analysis of diabase from New Market, Frederick County, is as follows:

*Analysis of Triassic Diabase from Near New Market, Md.**

SiO_2	51.28	H_2O^+	0.39
Al_2O_3	15.07	H_2O^-	0.09
Fe_2O_3	1.12	TiO_2	0.78
FeO	9.31	P_2O_5	0.13
MgO	7.97	S	0.06
CaO	11.42	Cr_2O_3	0.05
Na_2O	2.03	Mn O	0.16
K_2O	0.27		

An analysis of the diabase in a dike in Pennsylvania, the extension of the dike at Roller, Carroll County, is published in the Maryland Geological Survey's report on Baltimore County.[78]

Condition which favored the widespread Triassic faulting that accompanied and followed the deposition of Triassic sediments produced joint fractures and lines of weakness. The diabase magma rose along these joints and produced the system of diabase dikes now exposed in the Triassic rocks and the adjacent older rocks. These dikes are feeders of the large widespread masses of diabase that were intruded as sills and crosscutting stocks in the Triassic sedimentary rocks in Pennsylvania. Only the southern edge of these sills entered Maryland, where they are exposed just north of Emmitsburg.

Metamorphism of Intruded Triassic Sedimentary Rocks.—The Triassic sedimentary rocks adjacent to the diabase sills and the thicker dikes have been metamorphosed by the heat and vapors that accompanied the intrusion of the molten rock. A wide zone of such altered rock bordering the two sills of diabase north and northeast of Emmittsburg, is shown on the Frederick County map. Narrow zones of baked shale are present also on the borders of the thicker dikes east and north of Rocky Ridge and at LeGorge Bridge. The metamorphism has hardened the rocks and changed their color, and has developed new minerals, such as epidote and cordierite. Red shale becomes dull red, then dark purple, and almost black at the diabase contact, due to the deoxidation of red ferric oxide in the presence of some reducing agent. Sandstones are hardened by the baking, but the color change is less than in the red shale.

STRUCTURE

GENERAL DESCRIPTION

The Catoctin Mountain-Blue Ridge anticlinorium crosses western Frederick and eastern Washington counties. The anticlinorium is on the east border of the Great

* Shepherd, E. S., The gases in rocks and some related problems. Am. Jour. Sci., 5th ser., vol. 35A, pp. 336–337, 1938.

[78] Knopf, E. B., and Jonas, A. I., op. cit., p. 139.

Valley and is part of a linear uplifted belt which forms the Appalachian Mountains in southern Pennsylvania, Maryland, and southwestward. Intrusive rocks of early pre-Cambrian age are exposed in the core of the uplift. Overlying effusive rocks of late pre-Cambrian age and Lower Cambrian quartzites are enclosed in synclines on the flanks of the uplift. The western border of the anticlinorium is a major thrust fault, the Harpers Ferry overthrust. The Triassic border fault separates the Blue Ridge uplift from the Frederick syncline.

East of the Frederick syncline is a belt of closely folded, metamorphosed crystalline schists which cross the Piedmont upland of eastern Frederick County and Carroll County. The Martic overthrust forms the western border of the schists. In southeastern Carroll County rocks of early pre-Cambrian age occur in an anticline in the schists. These structural features are all of Paleozoic age.

Triassic rocks which lie east of the Blue Ridge uplift have been gently tilted by Triassic movements. The Triassic rocks are displaced by normal vertical faults which also offset older structures. The Triassic border fault is the most continuous of the normal faults. It has uplifted the Catoctin Mountain-Blue Ridge anticlinorium in respect to the Triassic rocks and the rocks of the Frederick syncline. The structure of the counties will be discussed under the headings: Catoctin Mountain-Blue Ridge anticlinorium, Frederick syncline, structure of the Piedmont upland, and Triassic structures.

CATOCTIN MOUNTAIN-BLUE RIDGE ANTICLINORIUM

The anticlinorium in Frederick County consists of the Middletown anticline and two bordering synclines, the Catoctin Mountain syncline on the east and South Mountain syncline on the west. In the southern part of western Frederick County, the South Mountain syncline is a medial syncline between the Middletown anticline on the east and the Rohrersville anticline, in Washington County, on the west. The Elk Ridge syncline is the western syncline of the uplift. South of Harpers Ferry Elk Ridge continues southwestward into West Virginia and Virginia, where it is the main Blue Ridge. The Harpers Ferry overthrust lies at the western border of the anticlinorium. All of these structures extend southwest into Virginia, and the writers[79] have described them in that area. In Virginia the medial Short Hill syncline, which is the southward extension of the South Mountain syncline, dies out near Hillsboro, Loudoun County, at a point 10 miles south of Potomac River. South of Hillsboro the cores of the Middletown and Rohrersville anticlines expand to a broad uplift bounded on either side by faulted remnants of the Catoctin Mountain and Blue Ridge (Elk Ridge) synclines.

Middletown Anticline

The Middletown anticline, at Potomac River, forms an area 7 miles wide between the Catoctin Mountain syncline on the east and South Mountain syncline on the west. It trends nearly due north from the river, crosses Frederick County and the eastern part of Washington County, and extends into Pennsylvania. The injection complex of early pre-Cambrian age is exposed in the anticline in the area south of

[79] Jonas, A. I., and Stose, G. W., op. cit. Am. Jour. Sci., vol. 237, no. 8, pp. 576–577, fig. 1, 1939.

Middletown and U. S. Highway 40 (Fig. 5). It is bordered on the flanks at most places by the Catoctin basalt of late pre-Cambrian age. The Swift Run tuff at the base of the metabasalt borders the north end of the injection complex in the anticline, where the fold plunges north under the younger rocks. North of the plunging end of the fold, north of Middletown, metabasalt and aporhyolite are exposed at the surface across Frederick County because there dissection has not gone deep enough to expose the basement rocks. The volcanic rocks are folded into several longitudinal folds parallel to the bounding synclines which enclose Lower Cambrian quartzites on the flanks of the Middletown anticline.

Rocks of granitic and granodioritic composition of the injection complex also form the core of the Rohrersville anticline in Washington County. On the flanks of that anticline the injection complex is bordered and overlain by the volcanic series.

The massive intrusive rocks in the core of the Middletown and Rohrersville anticlines have a primary structure developed during intrusion and folding in early pre-Cambrian time. Lack of exposures makes it impossible to work out the details of this structure. When the anticlinorium was formed in late Paleozoic time, the intrusive rocks rose as an arch and responded to compression by the development of a secondary eastward-dipping cleavage which transects the primary layering. This cleavage is common to the extrusive rocks of late pre-Cambrian age and to the Cambrian rocks of the bounding synclines. It was shown in the descriptions of the intrusive rocks of early pre-Cambrian age that the intrusives are cut by metadiabase dikes related to the Catoctin metabasalt (Fig. 6), and that the volcanic series to which the metabasalt belongs is of late pre-Cambrian age and was poured out on a floor composed of the injection complex of early pre-Cambrian age.

Keith[80] and Cloos[81] have described the granitic rocks of the Middletown Valley as intrusive in the volcanic series. The writers of this report have studied the injection complex and the late pre-Cambrian volcanic series and rocks of equivalent age in the Blue Ridge uplift from Pennsylvania to Alabama and have concluded that the granitic rocks of the injection complex do not intrude the volcanic series or rocks of equivalent age. In 1939 they[82] presented this conclusion and stated further that the volcanic series was poured out on a floor made up of the injection complex; that the volcanic series was not closely folded in late pre-Cambrian time but was affected by late Paleozoic orogeny which deformed the underlying injection complex and folded the overlying Paleozoic rocks. In 1941 Cloos expressed a similar opinion as to the age of the cleavage when he stated (p. 83) that "the cleavage in the volcanic series and Lower Cambrian rocks was formed in post-Cambrian and most likely in post-Ordovician times." He stated further, however, that "the cleavage direction within the volcanic rocks is followed by granitic intrusions in the Middletown Valley." In view of the fact that the cleavage is of Paleozoic age and that the granites are of early pre-Cambrian age, this statement is puzzling. It is the secondary cleavage in the granite that is parallel to the cleavage in the "greenstone" layers.

[80] Keith, A., op. cit. U. S. Geol. Surv., 14th Ann. Rept., p. 302, 1895.

[81] Cloos, Ernst, and Hietanen, Anna, Geology of the "Martic Overthrust" and the Glenarm Series in Pennsylvania and Maryland. Geol. Soc. Amer., Special paper no. 35, pp. 80, 83, fig. 29, 1941.

[82] Stose, A. J., and Stose, G. W., op. cit. Am. Jour. Sci., vol. 237, p. 592, 1939.

The primary layering of the granites is cut by the cleavage. It seems probable that the prominent cleavage common to all the rocks of the area may be in part the cause of the erroneous interpretation of the relations of the injection complex and the volcanic series. It is evident that the rocks of the injection complex were domed up during late Paleozoic compression and formed the Middletown and Rohrersville

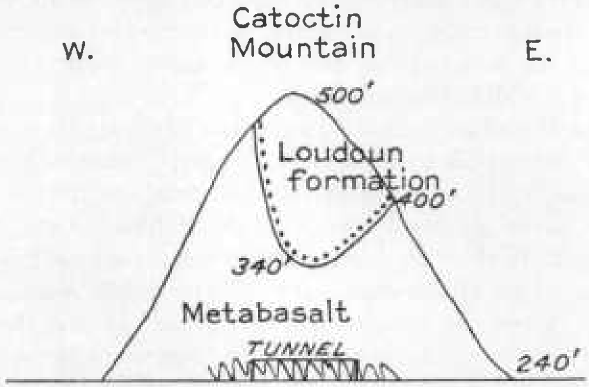

FIG. 20. Section of Catoctin Mountain in bluff on north side of Potomac River at Point of Rocks. Shows Loudoun formation in syncline above closely folded metabasalt at railroad level.

anticlines and that the mantle of layered rocks (the volcanic series and Lower Cambrian sediments) were enclosed in synclines between and bordering the anticlines.

Catoctin Mountain Syncline

The Catoctin Mountain syncline lies east of the Middletown anticline. It extends from Potomac River, near Point of Rocks, northeastward to a point 2 miles north of Mount St. Marys. Its maximum width is 3 miles, in the region east of Five Forks. The syncline encloses Lower Cambrian Loudoun formation and Weverton quartzite and is overturned to the northwest. On the west limb the Catoctin metabasalt dips southeast under the Loudoun formation and into the syncline. In places on the west limb, such as one-half mile west of Mountville and south of High Knob, the metabasalt and Loudoun formation are in minor folds on the west border of the syncline. In Eylers Valley, near the northeast end of the syncline, the metabasalt extends eastward into the mountain on a southeast pitching anticline which lies between Eagle Mountain and Roundtop. On the east side of the syncline a normal fault, with down-throw to the east, cuts off the metabasalt and a large part of the Loudoun formation, and in places it cuts off the whole east limb of the syncline. From Potomac River northward to a point near Braddock Heights the syncline is a single fold. Northeastward the fold is composite.

At Point of Rocks on Potomac River the syncline pitches north and the Lower Cambrian rocks at the south end of Catoctin Mountain do not reach the river level but lie above the 340 foot contour (Fig. 20). The underlying Catoctin metabasalt in the center of the syncline, exposed in the cut and tunnel of the Baltimore and Ohio Railroad, is greatly contorted and the minor folds are overturned to the northwest. The Loudoun formation in the cliffs above the river and to the northeast is enclosed in two tight overturned synclines. Northward the syncline deepens, and 3 miles north of Point of Rocks, at Pine Rock, the east slope of the mountain is a thick plate of southeast-dipping Weverton quartzite on the west limb of the syncline. The east limb is cut out by the bounding normal fault. The syncline rises northeast of Pine Rock and continues northeastward as a single overturned fold to the vicinity of Ridge Hill.

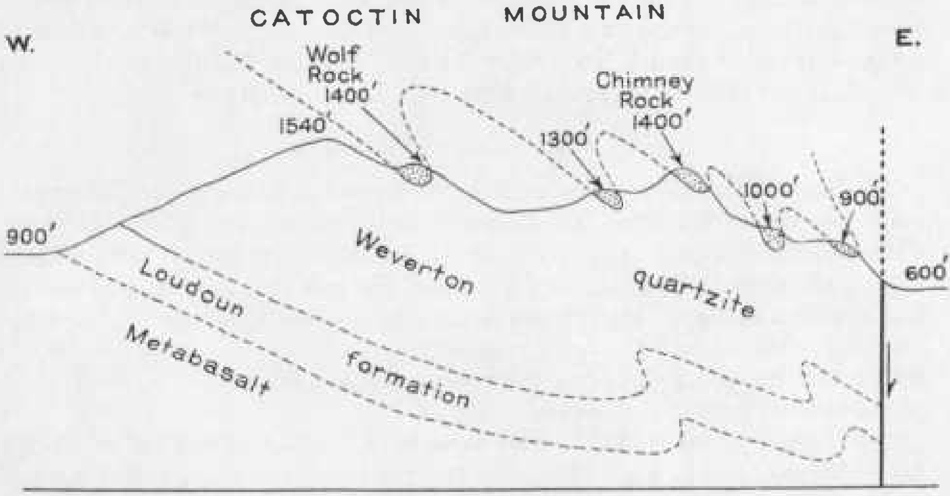

FIG. 21. Section across Catoctin Mountain north of Hunting Creek. Shows tight synclinal infolds of upper white quartzite of the Weverton at Wolf Rock and Chimney Rock

In the region from Ridge Hill northward to Hunting Creek, the syncline is composite. The minor folds are overturned to the northwest, and most of the rocks dip southeast. (See structure sections on Frederick County map and fig. 5.) North of Ridge Hill, a distinct syncline lies west of the trend of the main syncline that passes through Ridge Hill, and the Weverton quartzite in the center of this syncline forms High Knob (Pl. 7A). The Catoctin metabasalt and Loudoun formation form the west flank and south end of the fold. From a point northwest of Yellow Springs northward to Owens Creek, the composite character of the syncline is made evident by three or more infolds of the upper hard quartzite of the Weverton, which makes curving linear ridges. The Hamburg fire tower north of North Branch of Little Tuscarora Creek is located on one of these (Pl. 8A). Most of the streams have cut through the upper quartzites in the synclines and expose lower beds. On either side of the gorges of Fishing and Little Hunting Creeks, synclinal ridges of the upper quartzite of the Weverton make cliffs high above the streams, such as Salamander Rock, Black Rock, and Bobs Hill. North of Hunting Creek the upper quartzite in the synclines forms Cat Rock, Wolf Rock, and Chimney Rock (Pls. 7B, 9, and fig. 21).

From Potomac River northward as far as Thurmont, the bounding fault along the east foot of Catoctin Mountain is nearly parallel to the trend of the synclinal folds. Northwest of Thurmont, where the fault changes its strike and trends north, it cuts off the eastern folds, so that at the gorge of Hunting Creek and northeastward the syncline is composed of a single western fold. At Owens Creek the upper quartzite of the Weverton in this fold descends to the stream level in two prominent ledges which form an overturned syncline (Fig. 9). The east limb dips 50° SE., and the west limb 30° SE.

Roundtop and Carrick Knob, at the northeast end of Catoctin Mountain, are made of the dissected northwest limb of the syncline. The higher spurs are capped by the southeast-dipping plate of the upper hard beds of the Weverton quartzite. At the east end of Carrick Knob ridge, the syncline is terminated abruptly by the Triassic border fault, which extends north from Mount St. Marys.

South Mountain Syncline

The South Mountain syncline extends northeastward from Potomac River at a point just east of Weverton (Washington County) to Pen Mar at the Maryland-Pennsylvania State line. The axis of the syncline follows the Frederick-Washington County line along the crest of South Mountain, and only the eastern part of the fold is in Frederick County. The syncline encloses the Loudoun formation and Weverton quartzite. The late pre-Cambrian volcanic series, which underlies the Loudoun, is folded with the Lower Cambrian rocks and south of Lambs Knoll occurs at most places on both limbs of the syncline.

The syncline trends N. 10° E. from Potomac River to Lambs Knoll as a single fold. North of Lambs Knoll to Turners Gap the syncline has a curving strike, and north of that gap to Bartman Hill it again trends N. 10° E. North of Smoketown Gap, the Pine Knob syncline, which lies east of the axis of the fold at Bartman Hill, becomes the main syncline and extends northward out of Frederick County into Washington County (Fig. 5).

The synclinal character of South Mountain is best shown at Lambs Knoll, where the fold is open and the syncline is wide. Nearly horizontal beds of the upper quartzite in the center of the fold cap the knoll. North of the knoll the lower beds of the Weverton are folded into a series of eastward-trending folds which extend to Reno School. The Loudoun formation is exposed on the limbs of these folds. South of Lambs Knoll the syncline is overturned to the west, and the beds dip 35° E. In that region the Loudoun formation is believed to be present on both limbs of the syncline, but on the west side it is concealed by talus of Weverton quartzite. On the east limb the Loudoun dips 35° SE. (overturned) under the Catoctin metabasalt. The crest of the mountain is capped by a plate of upper quartzite of the Weverton in a closed syncline. At Crampton Gap the upper quartzite is eroded. The syncline deepens from the gap southward to Potomac River. Just east of Weverton, the river has cut through the syncline. The Weverton quartzite appears to be a continuous sequence of parallel beds in the cliffs north of the river and of U. S. Highway 340. The repetition of layers of like composition and thickness, however, suggest an isoclinal overturned syncline (Fig. 22). On the west limb, the full thickness of the Loudoun formation and Weverton quartzite occurs; on the east limb the lower beds of the Weverton, the Loudoun formation, and the Catoctin metabasalt are faulted out by a local thrust fault.

North of Lambs Knoll, in the vicinity of Fox's Gap, the syncline curves east around a reentrant valley. At the gap the syncline is narrow and is broken by an eastward-trending shear fault which is marked by a prominent quartz vein. Only the lower quartzite of the Weverton and the Loudoun formation on the east limb of the fold are present at the gap on the western border of the Harpers Ferry overthrust block. The shear fault appears to have weakened the rocks so that erosion

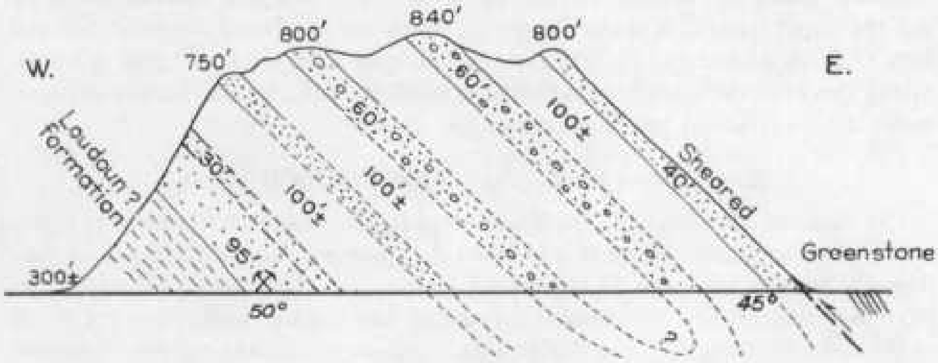

FIG. 22. Section of Weverton quartzite in South Mountain in bluff on north side of Potomac River east of Weverton. The structure is interpreted as an overturned isoclinal syncline enclosing conglomeratic quartzite of the upper part of the Weverton in the center of the fold.

has cut deeply into the overthrust block and has removed the west limb of the syncline. Northeast of Fox's Gap the syncline trends N. 10° E. to Bartman Hill. On U. S. Highway 40 at a point ½ mile west of Turners Gap, lower quartzites of the Weverton on both limbs of the syncline are well exposed. The rocks on the west limb dip 80° E. and those on the east limb dip 30° W. In the center of the fold the bedding is obscured by southeast-dipping cleavage. The Loudoun formation on the east limb of the fold is overturned and dips east toward the Catoctin metabasalt which lies just east of the gap. The syncline deepens northward, and in Monument Knob encloses the upper quartzite of the Weverton. At the crest of the knob the dips are vertical; farther north they are 30° E. and the quartzite forms a plate that dips down the east slope. At Bartman Hill the syncline rises and the upper quartzite has been eroded.

North of Smoketown Gap another syncline, the Pine Knob syncline, lies east of the strike of the main syncline at Bartman Hill. Just north of the gap the Loudoun formation curves eastward around the south end of the Pine Knob syncline and dips gently northward into the syncline. At the east side of Smoketown Gap, the volcanic slate that underlies the Loudoun is closely folded and the minor folds pitch north into the syncline. The upper quartzite of the Weverton in the center of the syncline caps the top of Pine Knob and the ridges to the north. There the syncline is overturned and the Loudoun formation on the east limb of the fold dips 50°–70° SE. About 1¼ miles north of Pine Knob the syncline is double; the western fold extends from Calico Rock northward through Black Rock to the rocky spur north of this cliff and ends south of the stream which branches from Beaver Creek at Mt. Aetna

School. This western syncline is in strike with the main syncline at Monument Knob and Bartman Hill.

The Pine Knob syncline trends N. 10° E. and extends in that direction for 7 miles to a point 1 mile east of Cavetown, in Washington County, where the Harpers Ferry overthrust cuts diagonally across it and truncates it. North of that point the northern part of the South Mountain syncline, which is in strike with the Pine Knob syncline, widens and deepens in the vicinity of High Rock and Quirauk Mountain and the upper quartzites of the Weverton, which cap the broad mountain top and form Quirauk Mountain, dip into the syncline from both sides. In Pennsylvania, east of Pen Mar, the syncline rises northeastward, and the Loudoun formation passes under the Weverton at the north end of the syncline.

Narrow Fault Block at East Foot of Catoctin Mountain

The Catoctin Mountain and the South Mountain synclines enclose no beds higher than Weverton quartzite, but it is believed that younger overlying formations were formerly present and have been removed by erosion. The rocks in the synclines have been subjected to deep erosion because of their uplifted position on the flanks of the Catoctin Mountain-Blue Ridge anticlinorium, which has been domed up and thrust upward on the Harpers Ferry overthrust. The anticlinorium has also been raised in respect to the rocks to the east during Triassic block faulting. Fanglomerates at the west border of the Triassic sedimentary rocks in Pennsylvania contain blocks and fragments of limestone derived from the erosion of the uplifted blocks west of the border fault, indicating that limestone beds were present above the quartzite in that block when it was uplifted.

A long narrow wedge of rocks lie between the Triassic border fault and a parallel normal fault east of the Catoctin Mountain syncline. This fault block extends from Potomac River northeastward to Catoctin. Its maximum width is 1¼ miles at a point ¾ mile east of Braddock Heights. The fault block contains Harpers phyllite overlain by Antietam quartzite and Tomstown dolomite, which in the Great Valley overlie the Weverton quartzite in normal stratigraphic sequence. The beds all dip southeast. It seems probable that this faulted wedge may be a remnant of a part of the Catoctin Mountain syncline which contained beds younger than the Weverton quartzite that were preserved because of their down-dropped position.

Harpers Ferry Overthrust

The Harpers Ferry overthrust bounds the west side of the Catoctin Mountain-Blue Ridge anticlinorium and has carried this uplift westward over rocks of the Hagerstown Valley. The overthrust lies entirely in Washington County (Fig. 5). At the north the overthrust enters Maryland at Pen Mar and trends S. 15° W. along the west foot of South Mountain to a point ¾ mile east of Rohrersville. From Pen Mar to that point the Loudoun formation and Weverton quartzite in the South Mountain syncline are on the western border of the overthrust. At the point ¾ mile east of Rohrersville, the overthrust bends sharply westward across the trend of the Rohrersville anticline, then swings around the north end of Elk Ridge, and there turns southwestward and follows the west foot of Elk Ridge to Harpers Ferry.

On the Frederick County geologic map two nearly parallel thrust faul s were shown west of the Pine Knob syncline. The eastern fault, called the B'ack Rock overthrust, was placed just below the quartzite cliffs of Black Rock. The map shows the fault trending south along the east side of the Weverton quartzite in the South Mountain syncline at Bartman Hill and Monument Knob and passing southward into the Blue Ridge uplift at Reno School. Although in places along this zone there may be evidence that suggests a fault, the writers now believe that the Black Rock overthrust does not exist (see revised mapping, Fig. 5). The Harpers Ferry overthrust west of Black Rock is at the base of the Weverton quartzite below the Black Rock cliffs, but its exact position is concealed by talus of quartzite. The Weverton in the cliffs is thrust over Antietam quartzite and Harpers phyllite. The phyllite also is largely concealed by the talus. Southwest of Bartman Hill, the Harpers Ferry overthrust overrides the Harpers phyllite in the core of the Locust Grove anticline. West of Fox's Gap, phyllite, formerly mapped as Loudoun formation and regarded as part of the west limb of the South Mountain syncline in the Harpers Ferry thrust block, is now considered to be Harpers phyllite in the overridden block, which is exposed in the reentrant valley west of Fox's Gap by erosion of the overthrust plate (Fig. 5). This phyllite lies east of a synclinal belt of Antietam quartzite on the east side of the Locust Grove anticline (Fig. 23). The writers have not modified the trace of the Harpers Ferry overthrust nor the structure in the autochthonous block in the area around Rohrersville.

In the region northeast of Rohrersville, the Harpers Ferry overthrust has a northerly direction, which is parallel in general to the trend of the South Mountain syncline on the border of the thrust. This trend is parallel also to the fold axes in the valley rocks which lie west of the thrust. In many places the Weverton quartzite of the overthrust block dips west toward the Harpers phyllite, which stratigraphically overlies the Weverton quartzite. The simplest interpretation of these relations is that the Weverton quartzite in South Mountain and the Harpers phyllite adjacent on the west are in normal sequence. On the geologic map of Washington County[83] these two formations are so mapped from Pen Mar southward to a point 1½ miles west of Lambs Knoll (Fig. 24). The following observations disprove this interpretation. In the broad part of South Mountain, from Calico Rock north to the spur north of Black Rock, the upper quartzites of the Weverton are clearly in a syncline and lower beds of the Weverton are adjacent to Antietam quartzite, and no Harpers phyllite crops out. West of Fox's Gap lower quartzites of the Weverton are at the contact with Harpers phyllite, and upper beds of the Weverton are absent between them. Folds in the valley rocks trend into and abut against the rocks in the South Mountain syncline, as is shown southwest of Pine Knob. There the Antietam quartzite on the east side of the Locust Grove anticline is cut off and the underlying Harpers phyllite lies adjacent to the Weverton in the South Mountain syncline. The Antietam quartzite appears again at a point just south of U. S. Highway 40, and trends south for a distance of three miles to a point where again it abuts against the Weverton quartzite in the South Mountain syncline. These discrepant relations can be explained only by a thrust fault.

[83] Cloos, Ernst, Geologic map of Washington County. Md. Geol. Surv., 1941.

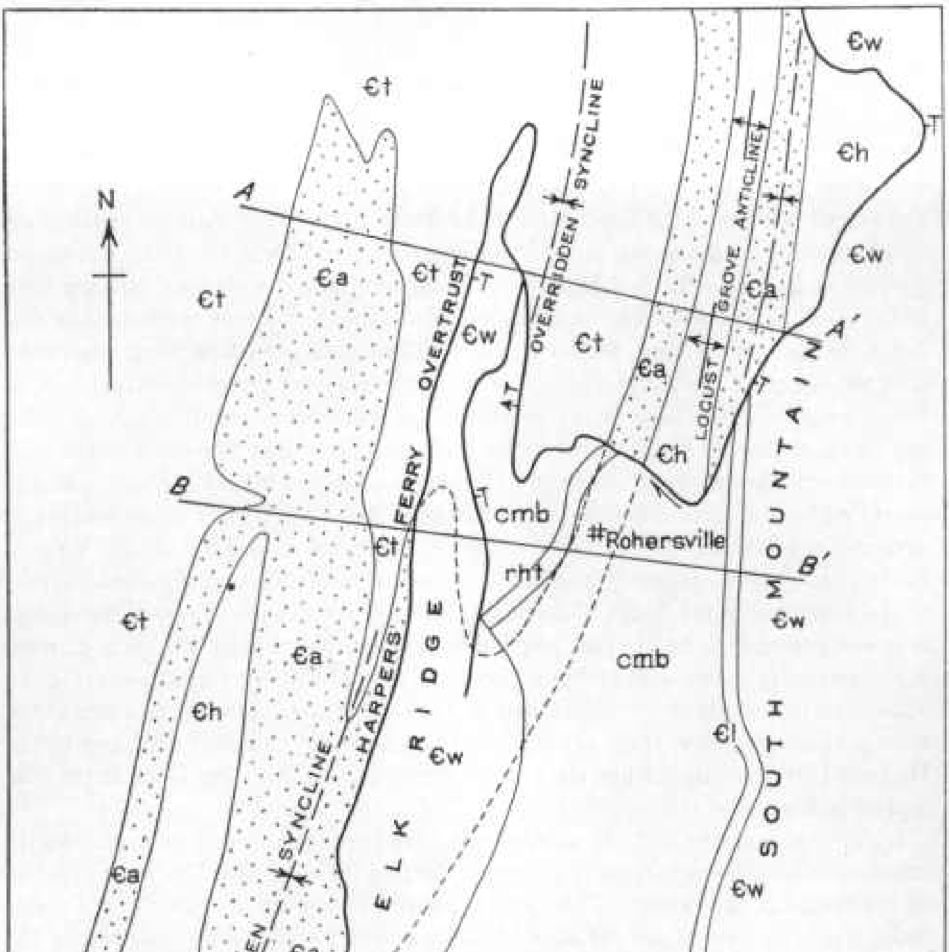

FIG. 23. Geologic map and sections showing the Harpers Ferry overthrust in the vicinity of Rohrersville, Washington County. Shows the Harpers Ferry fault block to be a thin plate thrust over the Antietam quartzite and Tomstown dolomite in the Eakles Mill syncline. *cmb*, Catoctin metabasalt; *rht*, rhyolite tuff in the metabasalt; €*w*, Weverton quartzite; €*h*, Harpers phyllite; €*a*, Antietam quartzite; €*t*, Tomstown dolomite.

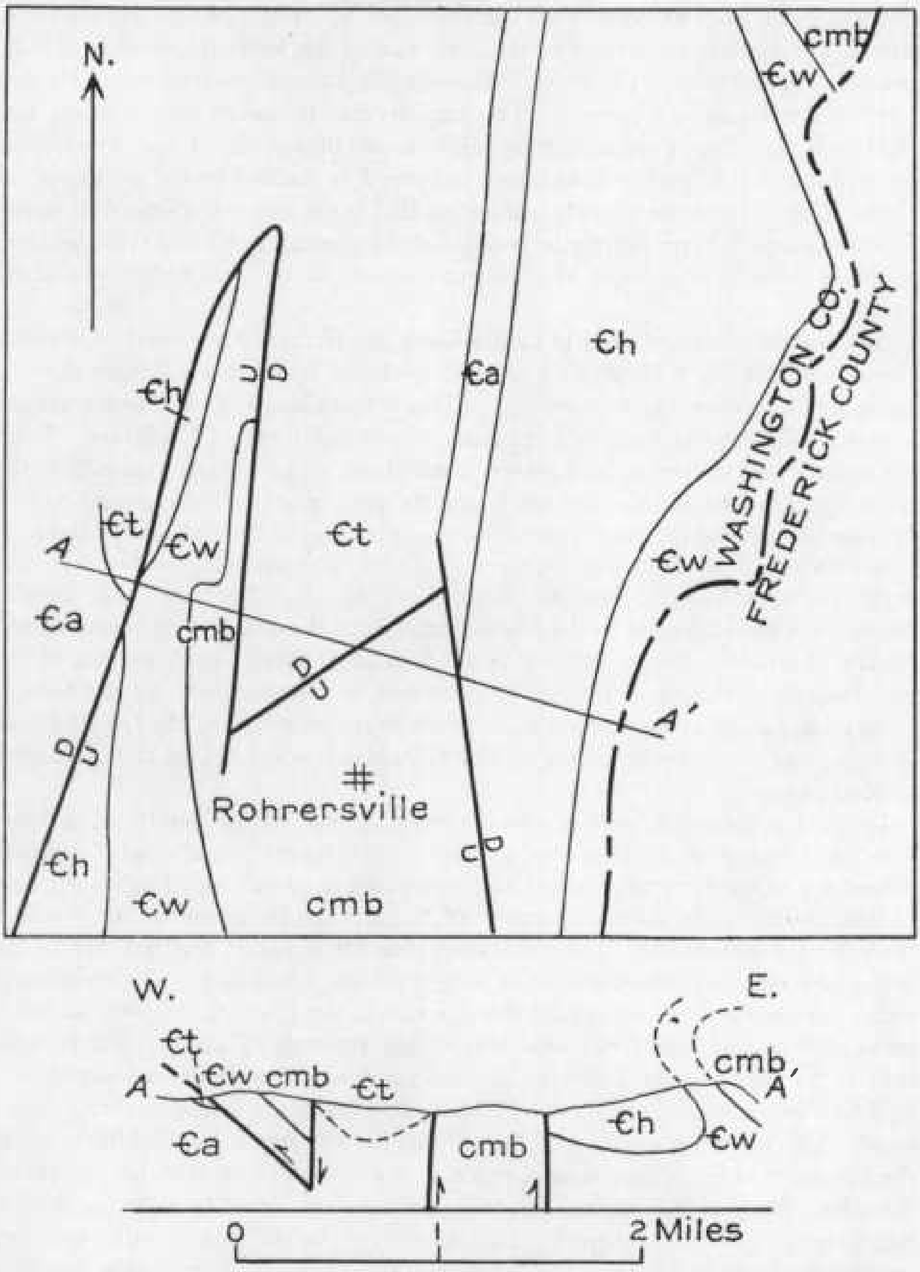

FIG. 24. Geologic map and sections of vicinity of Rohrersville from Geologic map of Washington County by Ernst Cloos. Md. Geol. Surv., 1941. *cmb*, Catoctin metabasalt; €*w*, Weverton quartzite; €*h*, Harpers phyllite; €*a*, Antietam quartzite; €*t*, Tomstown dolomite.

In the area northeast of Rohrersville, the fault trace lies along the lower west slope of South Mountain, which commonly is covered by a talus of quartzite from the mountain, and no exposure of the overthrust was seen. In the deep valleys north of Black Rock and east of Mt. Aetna School, where near-outcrops of the thrust were found, the black quartzite of the lower part of the Weverton dipping 20° SE., lies adjacent and in close proximity to east-dipping Antietam quartzite, and Harpers phyllite is not visible, if present. The relations seen in these valleys indicate that the thrust plane lies at about 1000 feet altitude and dips about 20° E. The sinuous trace of the fault in that area, as shown in figure 5, is justified by the low dip of the thrust plane. The writers conclude therefore that in the region northeast of Rohrersville, the Harpers Ferry overthrust is established by stratigraphic and structural discordance of the rocks of South Mountain to the rocks in the Great Valley west of the mountain.

At a point 2 miles southwest of Lambs Knoll, the Harpers Ferry overthrust leaves the west foot of South Mountain and bends west, and trends in a curving strike to a point $\frac{1}{2}$ mile northwest of Rohrersville. There it turns N. 10° W. and passes around a narrow hill of quartzite, which is the attenuated north end of Elk Ridge. From the point where the thrust fault leaves South Mountain and bends westward to the quartzite hill at the north end of Elk Ridge, the overthrust relation is clearly evident because the trend of the fault is directly across the trend of the rocks in the Rohrersville anticline. The fault cuts off rocks of the injection complex and bands of volcanic slate in the volcanic series in this anticline (Fig. 25). The thrust fault likewise transgresses the structures in the Lower Cambrian rocks of the Hagerstown Valley, namely the Locust Grove anticline, a syncline of Antietam quartzite east of the anticline, and outcrops of Harpers phyllite east of the syncline. All the beds in these folds, as well as the Tomstown dolomite on the west limb of the Locust Grove anticline and in the center of the Eakles Mills syncline, are cut off at right angles to their strike.

Detailed evidence of fault relations along this part of the overthrust follows. The near-outcrop of the fault contact of the Catoctin metabasalt and Tomstown dolomite is exposed in a tributary of Antietam Creek north of a road $\frac{1}{4}$ mile northwest of Rohrersville. The dolomite dipping 30° N. crops out in the stream below a falls made by the metabasalt. The metabasalt near the dolomite and in a hill to the east is sheared to a greenstone schist with southeast schistosity. The metabasalt and a narrow band of interbedded rhyolite tuff in the Harpers Ferry thrust block trend northeast and are terminated abruptly by the fault (Fig. 25). The rhyolite tuff, at the near-contact with the dolomite north of Rohrersville, is sheared to a mylonitic sericite schist, and its trend is bent eastward by the drag of the fault movement. The Weverton quartzite in the hill that lies just east of Eakles Mill, which is the north end of Elk Ridge, is surrounded on the east and west sides by Tomstown dolomite. Harpers phyllite and Antietam quartzite are absent between the Weverton quartzite and the dolomite. The dolomite is in the Eakles Mills syncline, between the Locust Grove and McClellans Hill anticlines. Adjacent to the quartzite hill the dolomite dips southeast, whereas the quartzite at the north end of the hill dips northwest. The quartzite on the borders of the hill is schistose, crushed, and veined with quartz, and the schistosity dips southeast. In places the quartzite near the fault has become a sericite schist. These secondary structures in the quartzite may be seen along Antietam Creek, which cuts through the quartzite hill east of Eakles Mills, and along the Baltimore and Ohio Railroad which crosses the hill south of Mt. Brier. The structural and stratigraphic discordance between the Weverton quartzite and the Tomstown dolomite are evidence of the overthrust

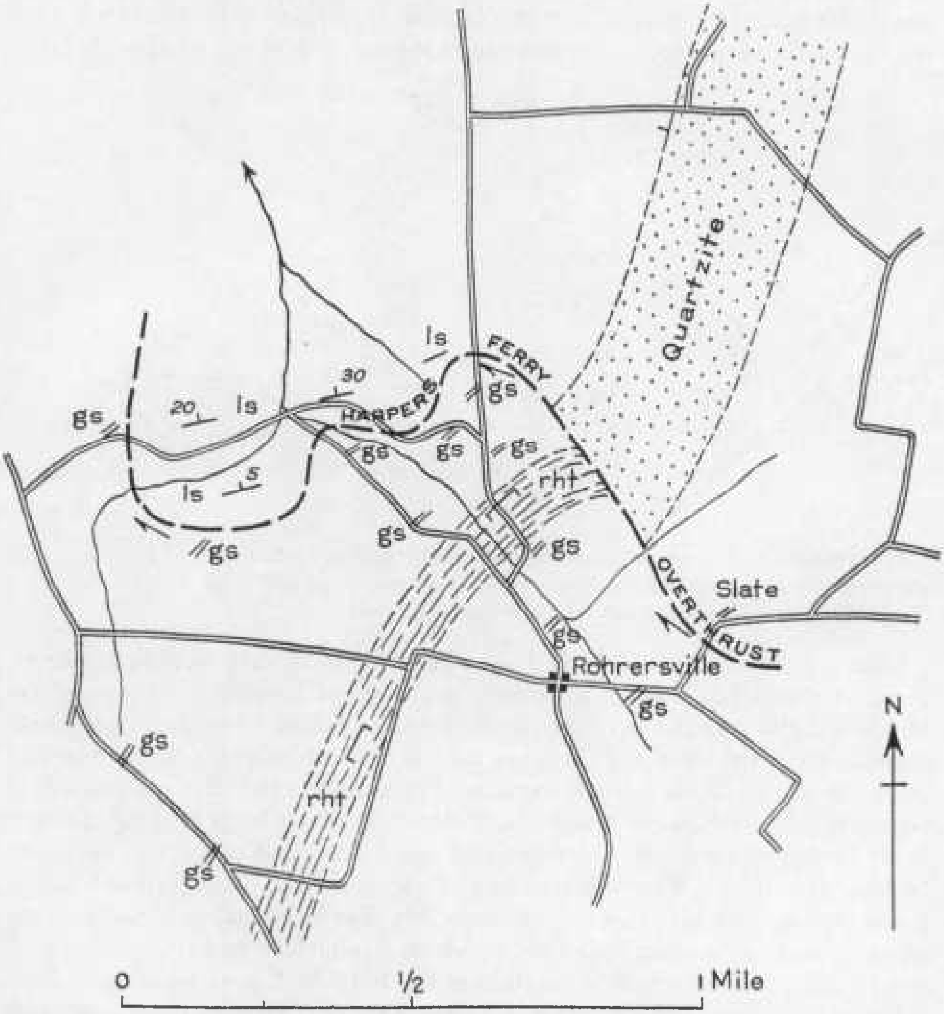

FIG. 25. Detailed geology in vicinity of Rohrersville showing rock outcrops. *gs*, greenstone (Catoctin metabasalt); *rht*, rhyolite tuff in the greenstone; *ls*, limestone, showing strike and dip of beds

position of the Weverton quartzite in the north end of Elk Ridge. Furthermore the deformation and crushing of the quartzite is such as occurs at the sole of thrust faults. The conclusion reached from all available evidence is that the quartzite in the north end of Elk Ridge is a remnant of a flat thrust plate left in its present position by erosion.

Southwest of the north end of the quartzite hill, the thrust fault follows the west side of Elk Ridge and cuts off the Tomstown dolomite in the Eakles Mills syncline.

Farther southwest it cuts off the Antietam quartzite on the east limb of the syncline. This belt of quartzite is the southwest continuation of the Antietam exposed on the east limb of the Eakles Mills syncline in the valley north of Rohrersville (Fig. 23). The Weverton quartzite of the north end of Elk Ridge and the underlying Catoctin metabasalt east of the quartzite are part of a thin thrust plate that overrides rocks of the Eakles Mills syncline and covers a part of the east limb of this syncline (Fig. 23).

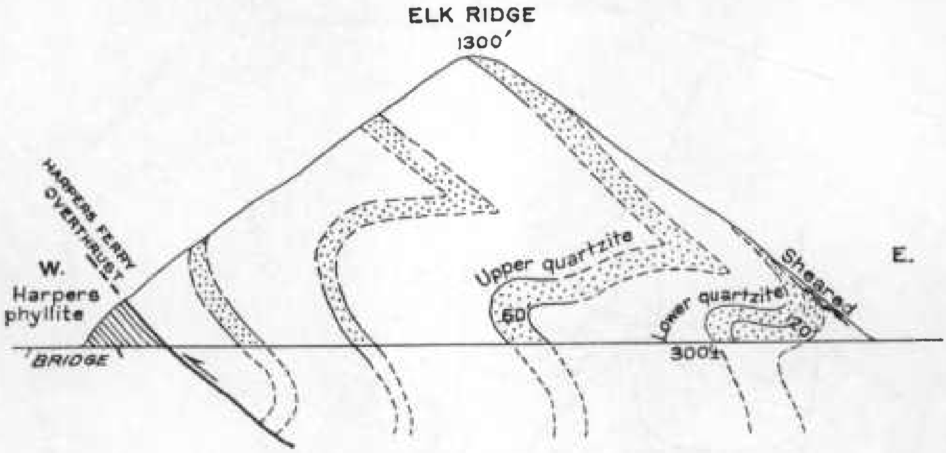

FIG. 26. Section of Weverton quartzite in Elk Ridge in bluff on north side of Potomac River. Shows recumbent anticline of lower beds of the Weverton in the Elk Ridge overturned syncline (Pl. 15A); upper ledge-making quartzite forms crest of ridges.

From a point six miles south of Eakles Mills southwestward to Potomac River, the quartzite in Elk Ridge is in contact with Harpers phyllite in the core of the McClellans Hill anticline and there parallels the trend of the overridden fold. Near Potomac River the contact of the thrust fault is not visible but the rocks above and below the thrust plane have a southeast-dipping cleavage. Harpers phyllite in exposures just north of the bridge over Potomac River on U. S. Highway 340 is a thinly laminated slate with a cleavage that dips 50° SE. and cuts across the folded bedding (Pl. 16B). Weverton quartzite of the overthrust block exposed in Elk Ridge east of the bridge on U. S. Highway 340, dips in general southeast and the white quartzite at the east end of the cut shows a recumbent fold (Pls. 15 and 16A, and Fig. 27). The structure of the rocks in Elk Ridge bluff is shown in figure 26.

In the region west and southwest of Lambs Knoll, the Harpers Ferry overthrust is shown on the geologic map of Washington County.[84] In the region north and northwest of Rohrersville, where structural discordance is most evident, the map of Washington County and the accompanying structure sections show vertical normal faults at or near the contact of Catoctin metabasalt and Tomstown dolomite north of Rohrersville and on the east side of the north end of Elk Ridge. In section C of that map a thrust fault is shown on the west side of the north end of Elk Ridge. (See Fig. 24 of this report.) The thrust fault is shown on the Washington County map as following the west side of Elk Ridge to a point near Mt. Brier, and there leaving

[84] Idem, Md. Geol. Surv., 1941.

the ridge and crossing Sharmans Branch in a south-southwest direction. In this part of the valley of Sharmans Branch it shows Harpers phyllite as thrust over Antietam quartzite to the west. The writers have found no evidence that the fault crosses Sharmans Branch, nor that Harpers phyllite underlies the valley where the fault is mapped. On the contrary they found ferruginous chert and yellow earthy

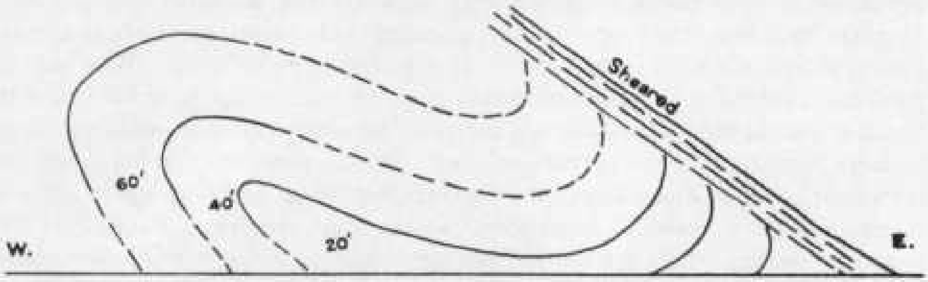

FIG. 27. Recumbent fold of lower ledge-making quartzite of the Weverton in bluff of Elk Ridge at Potomac River (Pls. 16A, 15B). Massive **hard** quartzite 100 feet thick underlain by softer quartzites.

tripoli, indicative of weathered limestone, north of the headwaters of Sharmans Branch, in strike with Tomstown dolomite which outcrops farther north. Furthermore, on the west side of the valley, where Sharmans Branch turns west through McClellans Hill, they found rusty weathering laminated quartzite, characteristic of the upper beds of the Antietam quartzite, dipping 10° E. toward the valley and presumably dipping beneath dolomite in the valley. The writers therefore conclude that the valley follows the Eakles Mills syncline which encloses Tomstown dolomite (Fig. 24).

The writers believe that their interpretation of the structural discordance in the vicinity of Rohrersville as a major overthrust fault which passes around the north end of Elk Ridge and extends southward along the west side of the ridge to Potomac River is confirmed by the field evidence, and that the interpretation shown on the Washington County map and sections is not correct.

The writers have traced the Harpers Ferry overthrust southwest of Harpers Ferry to Clarke County, Virginia, where they made a detailed study of the fault in 1942 for the Virginia Geological Survey. In Clarke County the trace of the overthrust is the western boundary of the Weverton quartzite, which, together with the underlying Loudoun formation and Catoctin metabasalt, has ridden northwestward on the fault over anticlines of Harpers phyllite and Antietam quartzite in the Great Valley. There the Weverton quartzite dips west toward the Harpers phyllite in apparent stratigraphic sequence. The evidence proves, however, that the Weverton is thrust over the Harpers. At many places beds of the Weverton quartzite are cut off along their contact with the Harpers phyllite, and at such places the quartzite is brecciated and veined with quartz. The trace of the contact is sinuous and has deep sharp embayments. The higher beds of the Weverton quartzite, present elsewhere in the region, do not occur in Clarke County and are believed to be absent because of thrust faulting. The structural axes in the overthrust mass are divergent to those in the rocks west of the fault. Anticlines of Antietam quartzite in the valley rocks are truncated by the fault. Although in Clarke County the trace of the Harpers Ferry overthrust has a general linear direction, in Warren County, to the southwest, it has a marked arcuate pattern. East of Front Royal, at the westward bulge in the overthrust mass, the stratigraphic break and structural discordance between the overthrust and overridden blocks are very marked. The Weverton quartzite and Loudoun formation, which form the western margin of the overthrust block in Clarke County, Virginia, are cut off by the fault 2½ miles east of Front Royal. West of that point the underlying Catoctin metabasalt is at the front of the fault block and is thrust across the ends of the Antietam quartzite, Tomstown dolomite, and succeeding younger formations in the overridden block. At the westward curving salient of the thrust block at Front Royal, the Catoctin metabasalt overrides Beekmantown limestone; and southwest of Front Royal, on the southwest side of the salient, the injection complex, which lies beneath the metabasalt, is thrust over the Beekmantown. It is evident that in this broad westward curving salient in the vicinity of Front Royal, the Harpers Ferry overthrust block has ridden far westward over the rocks of the valley and across their structures, which clearly pass under the overthrust mass and are covered by it. The overthrust there has a horizontal displacement of several miles and a stratigraphic break of several thousand feet.

The writers conclude that the Catoctin Mountain-Blue Ridge anticlinorium has ridden northwestward on a low-dipping thrust fault over rocks of the Hagerstown Valley; that the fault plainly transects and covers structures in the rocks of the Hagerstown Valley in the vicinity of Rohrersville and in the lowland adjacent to the north end of Elk Ridge; and that there the fault has a demonstrated displacement of four miles and probably has a much greater displacement.

In Maryland the injection complex is exposed only in relatively small areas in the southern part of the Blue Ridge uplift, but it lies at shallow depth under the late pre-Cambrian volcanic rocks in the entire uplift. It is evident from the relations of the rocks shown on the geologic map and in figure 5 that early pre-Cambrian rocks of the injection complex form the core of the thrust block and were involved in the major overthrusting. The massive intrusive rocks in the core of the anticlinorium did not fold but yielded to compression by the production of secondary cleavage which transects the primary layering. This cleavage transects also the overlying volcanic series and Lower Cambrian rocks. The crystalline basement rose during compression into a great arch and yielded also by breaking into great slices, one of which is the Harpers Ferry overthrust block, which moved westward over younger rocks of the Great Valley. The late pre-Cambrian volcanic series and the Lower Cambrian quartzites that mantle the injection complex were folded into sharp anticlines and synclines. The Harpers Ferry overthrust is on the western border of the South Mountain syncline and the Elk Ridge syncline. The overthrust is not the result of the breaking of an overturned anticline, but is a clean-cut break which originated in the basement rocks of the core of the uplift. The trace of the fault plane in the vicinity of Rohrersville and the narrow erosional remnant of the thrust slice at the north end of Elk Ridge indicate that there the fault has a very low dip, but the dip is probably much steeper at greater depth.

The injection complex extends from Maryland southward into Virginia where it is exposed in a wide area in the core of the Catoctin Mountain-Blue Ridge anticlinorium and underlies at shallow depth the mantle of late pre-Cambrian and Lower Cambrian rocks that lie on the flanks of the uplift. In the salient at Front Royal, the injection complex at the sole of the Harpers Ferry overthrust is in contact with Paleozoic rocks of the Great Valley. It is there demonstrated that the Harpers Ferry overthrust originated in the injection complex which was thrust upward and westward over rocks of the Great Valley. The Harpers Ferry thrust fault in Maryland and southwestward is, therefore, a fault of considerable magnitude, and is one of a series of clean-cut thrusts which originated in the injection complex and which border the west front of the Appalachian Mountains from Maryland southward into Virginia and Tennessee.

FREDERICK SYNCLINE

The Frederick syncline crosses Frederick County from the vicinity of New Midway to Potomac River. Its minor folds trend N. 20° E. The syncline is covered on the north, northwest, and west by Triassic sedimentary rocks, but the Frederick limestone exposed at the foot of Catoctin Mountain in the vicinity of Thurmont is part of the syncline. Together with the Triassic rocks the syncline has been downfaulted on its western margin by the Triassic border faults. The axis of the main syncline extends S. 15° W. from a point one mile west of LeGore, and passes just east of Frederick and through Buckeystown. The syncline encloses the Grove limestone of Lower Ordovician age, which dips 10° to 20° into the syncline. The Frederick limestone on both sides of the syncline dips normally under the Grove limestone. At the rising end of the fold, just southwest of Buckeystown, the fold shows minor fluting, and minor folding is indicated also east of Frederick and at Fountain Rock, where the band of Grove limestone enclosed in the syncline widens. It reaches 2 miles in width west of Woodsboro, where the limestones pass under the Triassic cover. A minor syncline enclosing the Grove limestone lies northwest of Walkerville, and several narrow synclinal folds of Grove limestone are present west of Harmony Grove and northwest of Frederick.

The Frederick limestone on the flanks of the syncline dips gently toward the synclinal axis. Low anticlines on the east side of the fold bring Antietam quartzite to the surface, and narrow synclines between the anticlines enclose the Frederick limestone. This limestone in the eastern part of the fold has a southeast dipping cleavage. The Martic overthrust cuts off the east side of the syncline, east of these anticlines. The main anticline of Antietam quartzite starts at Tuscarora at Potomac River, trends N. 15° E., and plunges northeastward in the vicinity of Frederick Junction. At the northeast end of Frederick Valley, Laurel Hill is a linear anticlinal fold separated by a minor syncline from another parallel anticline to the east, which extends southwestward to a point one mile southwest of Hopeland where it is cut off by the Martic overthrust. East-dipping cleavage is the prominent structure in the quartzite in these uplifts; where bedding was observed the dips are southeast. In a short anticline which lies west of Monocacy River and is crossed by U. S. Highway 40, the beds of the Antietam dip normally under Frederick limestone.

Although the Frederick syncline is just east of the Catoctin Mountain syncline, the writers do not regard it as a deeper part of the Catoctin Mountain syncline in which higher beds are preserved because of their down-dropped position. As has been previously stated, beds which are higher than the Weverton quartzite and which are believed to have been a part of the Catoctin Mountain syncline are preserved south of Catoctin in a narrow down-faulted block between the Catoctin Mountain syncline and the Frederick syncline. The rocks in that fault block are characteristic of the normal sequence of the Great Valley; that is, Lower Cambrian Tomstown dolomite overlying Lower Cambrian Antietam quartzite and Harpers phyllite. The Frederick syncline contains a different sequence: Upper Cambrian and Lower Ordovician limestones unconformably overlying Antietam quartzite. The Frederick syncline in Frederick County passes northeastward under Triassic sedimentary rocks. It appears again in Pennsylvania in the Hanover Valley.[85] There the Conestoga limestone, which probably is in part the equivalent of the Frederick and Grove limestones, lies unconformably on Lower Cambrian rocks, including the Kinzers formation and associated dolomites which are a southeastern facies of the Lower Cambrian Tomstown dolomite (Fig. 15). In the Hanover Valley, the Lower Cambrian series and Conestoga limestone are on the south flank of the Pigeon Hills anticline, which exposes the Antietam quartzite and older rocks. This structure plunges northeastward and is covered on the northwest side by Triassic sedimentary rocks. Fifteen miles to the northeast another uplift exposing the quartzites, the Hellam Hills anticlinorium, is bordered on the south by the same sequence, the southeastern facies of the Tomstown dolomite and Conestoga limestone. This anticlinorium is thrust northwestward on the Chickies thrust fault over rocks of the Great Valley sequence, which contains the Tomstown dolomite and which does not have the southeastern facies of that dolomite and the Conestoga limestone. These two different series of equivalent rocks were evidently deposited in basins formerly widely separated across the strike but which have been brought closer together by overthrusting.

At the west end of the Hellam Hills anticlinorium the Chickies overthrust passes under Triassic sedimentary rocks. The overthrust is probably present but covered north of the Pigeon Hills uplift. The writers believe that the sequence of beds in the Frederick syncline differs from the sequence of equivalent beds in the Catoctin Mountain syncline and the Great Valley because they were deposited farther to the east under different conditions of sedimentation; that the Frederick syncline in Maryland is part of the Chickies overthrust block, which in late Paleozoic deformation was carried northwestward to the vicinity of the Blue Ridge uplift by overthrusting on the Chickies or a related thrust fault; and that later the overthrust block was down-dropped with the Triassic sedimentary rocks by the Triassic border faults so that only the younger rocks in the overthrust block are exposed.

AGE OF THE STRUCTURAL FEATURES IN THE CATOCTIN MOUNTAIN-BLUE RIDGE ANTICLINORIUM AND FREDERICK SYNCLINES

The Paleozoic rocks and the underlying pre-Cambrian rocks were folded and broken by thrust faults during a period of prolonged and intense compression. The

[85] Stose, G. W., and Jonas, A. I., Geology and Mineral Resources of York County, Pennsylvania. Op. cit., pp. 59-67 and pp. 142-148, 1939.

Triassic rocks in the area were not affected by this diastrophism which therefore is pre-Triassic in age. The structures in the area are parallel to, and probably a part of, the structural features in younger Paleozoic rocks that lie farther west in the Appalachian Valley, the youngest of which are of late Pennsylvanian or early Permian age. Although minor incipient folding probably took place during the deposition of the early Paleozoic sediments, giving rise to variation in thickness and even to minor overlap of formations, the main structural features in the Paleozoic rocks in the Great Valley, the Catoctin Mountain-Blue Ridge anticlinorium, and the Frederick syncline are believed to have been formed during the mountain-making epoch at the close of the Carboniferous or early in the Permian.

STRUCTURE OF THE ROCKS OF THE PIEDMONT UPLAND

General Description

Close folding characterizes the crystalline schists in Carroll County and the eastern part of Frederick County. The folds range in dimensions from major structures, which extend across the counties, to minute plications of microscopic size. The rocks have a schistosity which generally parallels the bedding and a transverse cleavage. These structures prevail over a wider area than these counties and extend into Pennsylvania and into Virginia. In southeastern Carroll County the western part of the Woodstock anticline exposes Baltimore gneiss and related rocks of early pre-Cambrian age. The major folds in the crystalline schists which lie on the west flank of the Woodstock anticline are the Tucquan, Westminster, and Hoffmans Mill anticlines and the Peach Bottom, Dug Hill, and Wentz synclines (Fig. 30). In the western part of the belt of crystalline schists, a series of anticlines with steeply-dipping fold axes extends southwestward from a point one mile west of Westminster to the vicinity of New Market. The Sugarloaf Mountain syncline, which is a part of the steep-axis structure, lies west of these anticlines, near the western border of the belt of crystalline schists. The belt of crystalline schists is part of the Martic overthrust block and is bounded on the west by the Martic overthrust, which lies east of the Frederick syncline.

Woodstock Anticline

A small part of the northwest border of the Woodstock anticline is in southeastern Carroll County and extends southward into Howard County. The largest part of the anticline lies in western Baltimore County. The Woodstock anticline is one of several uplifts which expose Baltimore gneiss, Hartley augen gneiss, and injection gneisses of early pre-Cambrian age in Harford, Baltimore, Carroll, Howard, and Montgomery Counties, Maryland. They are short oval uplifts surrounded in large part by the Setters formation, Cockeysville marble, and Wissahickon formation, which in general dip away from the gneiss on the flanks of the anticlines. In Carroll County, the Setters formation and Cockeysville marble dip about 25° NW. off the gneisses. On the flanks of the anticline in Carroll County and to the northeastward in Baltimore County, the Setters formation and overlying rocks form straight or gently curving borders to the uplift. Just northeast of the Carroll County line, in Baltimore County, these rocks are involved in a minor fold on the northwest limb of the anticline. More intense folding of the rocks overlying the gneiss occurs in Baltimore County on the south side of the Woodstock anticline.

Earlier in this report it was suggested that the crystalline schist series which overlies the Cockeysville marble and Setters quartzite on the flanks of the anticlines, in southeastern Carroll County and in neighboring parts of Maryland, may be an argillaceous sequence which was deposited in a different basin from that which received the normal valley sequence; that the Setters quartzite and Cockeysville marble may be Lower Cambrian and the lower part of the normal valley sequence, and rest in depositional contact unconformably on the Baltimore gneiss and associated rocks of early pre-Cambrian age. If such is the case, the Wissahickon formation on the flanks of the anticlines of Baltimore gneiss was not deposited in its present position on the Cockeysville marble but owes its present position to overthrusting. Whether the crystalline schists overlie the Cockeysville marble, Setters quartzite, and Baltimore gneiss in overthrust or in depositional relation, all of these rocks have been folded together and have structural features in common.

Peach Bottom Syncline

On the northwest flank of the Woodstock anticline, the Wissahickon formation and overlying Peters Creek formation are in close recumbent folds which are overturned to the southeast and the axial planes dip northwest into the Peach Bottom syncline. The syncline crosses southeastern Carroll County and extends S. 35° W. from a point near Glen Falls on North Branch of Patapsco River to the vicinity of Sykesville on South Branch of Patapsco River. It encloses the Peters Creek formation, which is closely folded into recumbent folds whose axial planes dip into the syncline. The syncline takes its name from Peach Bottom, Lancaster County, Pennsylvania, where the Peach Bottom slate and underlying Cardiff conglomerate overlie the Peters Creek formation and occupy the center of the fold and are involved in the folding. The syncline enters Maryland at Delta-Cardiff, extends southwestward across Harford and Baltimore Counties into Carroll County, crosses Carroll and Montgomery Counties, and passes into Virginia at Great Falls, Maryland.

In Carroll County, the Sykesville granite is intruded into the Peters Creek formation from a point near The Bunker southwestward to Sykesville, where the granite lies in the east limb of the syncline. Southwest of Carroll County it continues in that position across Howard and Montgomery Counties. At Potomac River it lies at the west edge of the District of Columbia. Throughout the extent of the granite its foliation dips northwest into the Peach Bottom syncline and away from the Woodstock, Highland, and Washington anticlines which lie a short distance east of the granite. The Sykesville granite is bordered by a contact zone in which it has injected the Peters Creek formation. The granite contains numerous xenoliths of the Peters Creek formation and hornblende gneiss. In Howard and Montgomery Counties the injection gneiss of the contact zone is folded into pitching folds whose axes dip 40° to 70° west or southwest. These secondary structures accord with folded structures in the Peters Creek formation and were produced in both rocks by the same orogeny. The xenoliths in the granite are not aligned with the folded structure, showing that the folds are not primary structures. It seems that the Sykesville granite was intruded before the regional folding, that deformation has produced secondary structures and in places may have rotated primary structures until they are parallel to the secondary. Its original shape was elongate, parallel to the trend of the Peters Creek formation, and deformation has modified its primary outlines. In Carroll County serpentine lies southeast of the Sykesville granite, where it intruded along the contact of the Wissahickon and Peters Creek formations. Its trend follows that of the enclosing rocks, and secondary foliation in the serpentine dips northwest with the dip of the enclosing rocks.

In the chapter on the mineral resources of the counties, are described the copper deposits of eastern Carroll County. There the ore-bearing solutions have replaced hornblende gneiss (metagabbro) and serpentine which crosses the county in a narrow dike on the northwest side of the Sykesville granite. Overbeck[86] concluded that the hornblende gneiss and serpentine were formed from gabbro and an ultrabasic rock by regional deformation. These mineralized basic rocks and the serpentine which is southeast of the Sykesville granite are part of the same intrusion, and similar and related rocks are exposed in Baltimore County in wide areas. The gabbro and ultrabasic rocks throughout their extent contain secondary structures[87] produced by deformation after their emplacement. The writers conclude that both the Sykesville granite and the basic and ultrabasic intrusives that now lie in the Peach Bottom syncline have been deformed by regional folding since their intrusion.

Tucquan Anticline

The Tucquan anticline is northwest of and parallel to the Peach Bottom syncline. It enters Carroll County at a point two miles southeast of Hampstead and extends southwestward across West Branch of Patapsco River just southeast of Patapsco, goes through Gist, and passes into Howard County at a point one-half mile west of Woodbine. The albite-chlorite schist facies of the Wissahickon formation is exposed in the anticline. The Tucquan anticline in Carroll County is the southwest continuation of the Tucquan anticline in York and Lancaster Counties, Pennsylvania,[88] where it passes northeastward into the Mine Ridge anticline. This anticline exposes the Batilmore gneiss (injection complex) of early pre-Cambrian age, which is overlain by Lower Paleozoic rocks on the flanks and the southwest plunging end of the uplift. These Paleozoic rocks plunge southwestward under the albite-chlorite schist of the Wissahickon formation. Mine Ridge anticline is a double arch, and the Tucquan anticline, which is its southwestward continuation in the Wissahickon formation, is also a double arch southwestward to a point near High Rock, York County, Pennsylvania. Southwest of that place, in Pennsylvania and across Baltimore and Carroll Counties, Maryland, it is a single fold. The albite-chlorite schist in the

[86] Overbeck, R. M., A metalographic study of the copper ores of Maryland. Econ. Geol., vol. 11, no. 2, pp. 167–178, 1916.

[87] Cohen, C. J., Structure of the metamorphosed gabbro complex at Baltimore. Md. Geol. Surv., vol. 13, pp. 215–236, 1937.

[88] Knopf, E. B., and Jonas, A. I., op. cit., Bull. 799, p. 73, 1929.
Stose, G. W., and Jonas, A. I., op. cit., Bull. C.67, pp. 152–153, 1939.
Stose, A. J., and Stose, G. W., op. cit., Prof. Paper 204, pp. 68–70, fig. 27, 1944.

anticline is closely folded, and in places the folds are flatly recumbent. The axial planes of these folds dip away from the crest of the arch. The layers are cut by a steeply-dipping transverse cleavage, which also dips away from the center of the fold. The fold axes dip gently southwest throughout the entire extent of the anticline. In southern Carroll County the folds are more open; farther to the southwest, in Howard County, the folds are tightly compressed and broken by a steeply east-dipping cleavage. There the Tucquan arch pitches south and appears to die out.

In northern Carroll County, from the crest of the Tucquan anticline northwestward to the Wentz syncline, the close folds are overturned to the southeast. There anticlinal folds are recognized by areas of Wakefield marble and Sams Creek metabasalt that are brought to the surface. The albite-chlorite schist occupies the intervening synclines. In that area the folds trend S. 35° W. and this southwestward trend continues through Westminster and across the western part of Carroll County and the eastern part of Frederick County. Major folds in that area include the Hoffmans Mill anticline, Tannery syncline, Westminster anticline, and Dug Hill syncline.

Hoffmans Mill Anticline

This fold is largely in the albite-chlorite schist of the Wissahickon formation. At Carrollton, on West Branch of Patapsco River, the anticline lies 2½ miles northwest of the Tucquan anticline. It extends from Carrollton northeastward through Hoffmans Mill and Greenmount, and enters Baltimore County at a point 1½ miles south of Roller. From a point ½ mile south of Hoffmans Mill northeastward for a distance of 3½ miles, the fold exposes Wakefield marble. In outcrops near Hoffmans Mill the marble is exposed in the center of a recumbent fold of albite-chlorite schist. The axial plane dips 15° NW. One-half mile south of Hoffmans Mill the fold pitches south. Northeast of Hoffmans Mill, along the same strike, a recumbent anticline again brings Wakefield marble to the surface in the vicinity of Millers and Alesia. There also the fold is overturned to the southeast and the beds dip 15° NW.

Tannery Syncline

From Tannery southwestward through Winfield to a point one-half mile west of Watersville, at the Carroll County line, the Wissahickon albite-chlorite schist occupies a syncline on the northwest side of the Hoffmans Mill anticline. The fold plunges gently southwestward. In northern Carroll County the syncline, like the adjacent folds, is overturned to the southeast. In exposures on South Branch of Patapsco River the closely folded layers of the schist and the transverse cleavage dip steeply northwestward into the syncline.

Westminster Anticline

In a belt about 2 miles wide, which extends from the Maryland-Pennsylvania State line in the vicinity of Black Rock and Lineboro southwestward through Westminster to the vicinity of Taylorsville, a series of anticlinal folds expose Wakefield marble and Sams Creek metabasalt. These anticlinal folds are separated by the Dug Hill Ridge and northern Parrs Ridge synclines. The synclines enclose the Wissahickon albite-chlorite schist. All of these anticlinal and synclinal folds are overturned to the southeast and the beds and the transverse cleavage dip northwest. Southwest of Westminster, Wakefield marble and the metabasalt, exposed in anticlines, plunge southwest under albite-chlorite schist. The metabasalt and marble along the trend of one of these anticlines are brought to the surface at a point between Parrsville and Ridgeville, and further west the metabasalt is brought to the surface in two anticlines west of Ridgeville. In the region just southwest of and northeast of Westminster, several of the anticlines are broken by minor thrust faults along which the rocks were moved southeastward. The faults cut off metabasalt and in places Wakefield marble on the southeast limb of the folds (Fig. 4). One fault extends northeast from near Warfieldsburg to Ebbvale. Other faults lie northwest of Bixler and extend northeastward, passing one half mile north of Ebbvale. At a point one half mile north of Manchester, a thrust fault, which extends northeast to the Maryland State line at a point one half mile east of Lineboro, has cut off the southeast limb of an anticline. The faults are marked at many places by deposits of limonite ore.

Wentz Syncline

The Wentz syncline lies in northern Carroll County on the northwest side of the Westminster anticline. It passes through Wentz with a curving strike and extends southwestward to the neighborhood of Union Mills. Quartzite and conglomerate of the Marburg schist are infolded in the syncline and are more prominent in the vicinity of Wentz where the syncline is deepest. The quartzite and conglomerate in several folds extend to Deep Run, where the syncline rises. Near Wentz the closely folded beds and the transverse cleavage dip northwest. At the southwest end of the syncline near Deep Run and Union Mills, the minor folds are overturned to the northwest and all the structures dip southeast. In the closely folded Marburg schist southwest of Union Mills and northwest of Union Mills, on the northwest side of the Wentz syncline, the Ijamsville phyllite and Silver Run limestone are exposed in anticlines in the Marburg schist. The anticlines are overturned to the northwest and the dip is southeast, and the minor folds pitch southeast or south. The pitch in these folds steepens in the vicinity of, and north of, the area of steep-axis structure, next to be discussed.

Area of Steep-Axis Structure

From a point 1 mile west of Westminster westward and southwestward across the western part of Carroll County and the eastern part of Frederick County, the fold axes pitch more-or-less steeply and the beds have a curving strike.[89] There the volcanic rocks and Wakefield marble, repeated across the strike several times, bend sharply in a four-fold series of long curves. The easterly of the southward curves turns northwest in the vicinity of Dennings and extends to Medford at the north. At Wakefield Mills the curving belt turns southwest again and extends through New Windsor to Weldon. There it curves northwest to Linwood. Southwest of Linwood the fold trends S. 10° W. to the vicinity of New Market and then turns north and extends to Union Bridge. The westerly fold extends south from Union

[89] Jonas, A. I., op. cit. Am. Jour. Sci., vol. 34, pp. 376–388, 1937.

Bridge to a point 1 mile west of New Market and then trends north and northwest to the vicinity of Centerville, where a Triassic normal fault cuts it off. The length of the two easterly curving folds is about 5 miles; that of the two westerly folds is about 15 miles. On the south and east sides of the belt of steep-axis structure, the pitch of the folds decreases in amount; and at West Falls, on the Carroll-Frederick County line, the fold axes are horizontal; nearby, near the south border of Frederick County, the pitch is not more than 10° S.

For reasons stated later, these southward-curving steep-axes folds are regarded as anticlinal. West and southwest of the westerly anticlinal fold, the Urbana phyllite and Sugarloaf Mountain quartzite are infolded into a syncline in which the minor folds pitch into the syncline and the strike of the formation curves near the center of the fold.

The east limb of the pitching anticlinal folds in the area of steep-axis structure is overturned to the east in conformity with structures in the adjoining region to the northeast, where all the beds dip northwest off the Tucquan anticline. The west limb of this fold and all the other folds to the west and southwest in the area of steep-axis structure, including the Sugarloaf Mountain syncline, are overturned to the northwest and the beds and the transverse cleavage dip southeast (Fig. 30).

In the steep-axis folds the pitch is south or southwest, and at the sharp curves in the strike the pitch is as much as 70°. In places southwest of Linwood in the two westerly anticlinal folds, in the vicinity of Oldfield and southwestward to New Market, the beds are contorted in sharp minor folds and trend east and west at right angles to the general nearly southerly trend. At the turn of the southward swing northeast of New Market, the trend is deflected to an east-west direction in a series of repeated curving folds. In places quartzites of the type of the Sugarloaf Mountain quartzite are infolded in synclines in the volcanic rocks and have a curving strike like that of the underlying rocks.

The explanation of curvilinear stratigraphic strike lies in the fact that the fold axes are steeply inclined and stand at a steep inclination to the surface, so that the surface outcrops present a cross section of the folds. Volcanic rocks show layering better than the Wakefield marble, and on horizontal surfaces the layers are seen to be in sinuous bands which form arches and troughs. The change in strike shown in these minor folds conforms to the major structure. In the vertical plane of these outcrops the rock layers form straight, vertical or inclined bands parallel to the fold axes, and represent the truncated crests and troughs of the folds. Lineation is shown on cleavage planes by amygdules drawn out in a direction parallel to the fold axes. It dips steeply where the fold axes have a steep dip. In places the volcanic rocks contain a second cleavage which lies diagonal to the bedding, and its intersection with the transverse cleavage planes is diagonal to the lineation. Tension joints, perpendicular to the fold axes, are developed in the volcanic rocks. In places these joints show as wrinkles at right angles to the lineation.

Sugarloaf Mountain Syncline

This syncline lies on the western border of the crystalline schist belt and west of the area of steep-axis folds. It encloses the Ijamsville phyllite, Urbana phyllite and associated quartzites, and the Sugarloaf Mountain quartzite. The syncline is overturned to the northwest and the beds dip southeast.

The deepest part of the fold is in Sugarloaf Mountain peak. The peak is a syncline overturned to the northwest, and the plate of quartzite which caps the peak and dips gently southeast is the west limb of the syncline. The east overturned limb

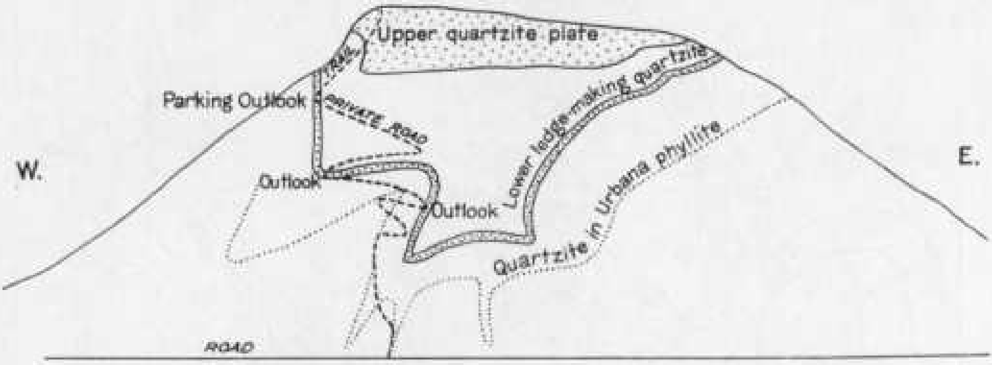

FIG. 28. Geology of Sugarloaf Peak viewed from the road west of Stronghold. Shows capping plate of upper quartzite and synclinal attitude of lower hard beds of the Sugarloaf Mountain quartzite and quartzite bed in the underlying Urbana phyllite.

has been removed by erosion. The synclinal structure of the mountain is shown on the detailed map (Fig. 16) and the cross section through the peak (Fig. 17). It is better illustrated in the sketch (Fig. 28) which pictures the lower quartzites as viewed from the road west of Stronghold. The lower ledge-making quartzite of the syncline extends around the east and west shoulders of the mountain, and on the south slope is closely folded. A quartzite near the top of the Urbana phyllite, lower in the fold, passes around the fold on the lower slope of the mountain and is exposed in close folds in many outcrops along the road west of Stronghold.

North of Sugarloaf peak the overturned syncline encloses only the lower hard beds of the Sugarloaf Mountain quartzite. This quartzite, on the west limb of the syncline, forms the crest of the main ridge. The quartzite on the east limb, which is overturned and dips 45° SE., makes a rocky spur that descends eastward into the hollow at the head of South Fork of Little Bennett Creek, and north of the hollow forms a long spur that becomes an eastern ridge of the mountain west of Thurston. Softer quartzose beds, above the lower ledge maker, are enclosed in the tight syncline between the parallel ridges (Fig. 29).

In the deep valley at the north end of the mountain, at the headwaters of Bennett Creek, the quartzites on the two limbs of the syncline come together and make a single, low, west-trending synclinal ridge which lies at the north foot of the main ridge. Here the quartzite is crushed and veined with quartz, and the dip of the beds was not determined. The Urbana phyllite north of the mountain at this point is closely folded, and the minor folds pitch south under the Sugarloaf Mountain quartzite. West of Bennett Creek valley, the syncline again widens and the lower hard quartzite on the limbs of the syncline forms two separate ledges. The quartzite on the south

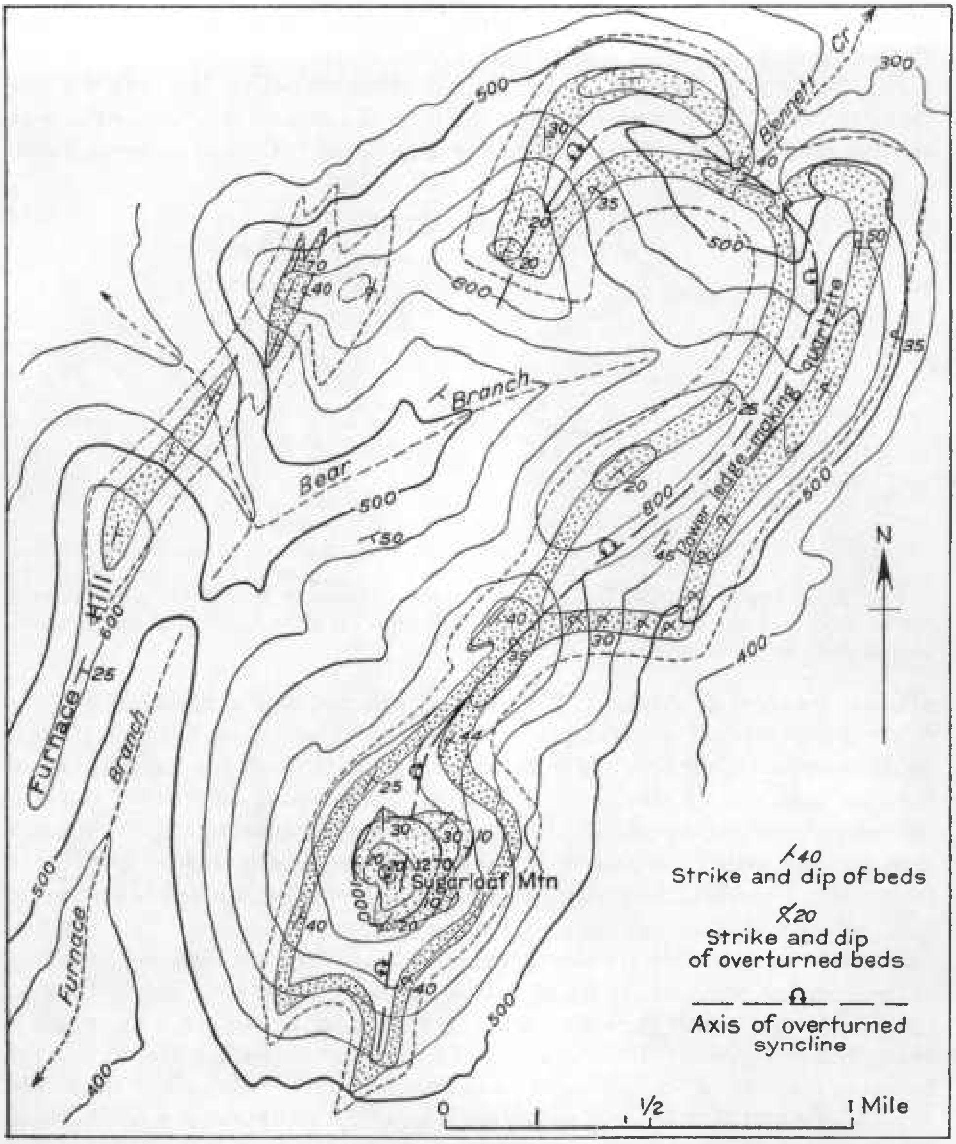

FIG. 29. Geologic map of Sugarloaf Range. Shows detailed geology, suggesting interpretations somewhat different from those shown on the county geologic map. Shows the axis of the Sugarloaf syncline bent into a horseshoe curve, and both parts of the syncline overturned toward the northwest. The upper cliff-making and lower ledge-making quartzites are shown by stipple pattern. The base of the Sugarloaf Mountain quartzite is shown by a dashed line.

limb, which is overturned and dips 35° SE., ascends the slope of the high knob to the southwest. The quartzite on the north limb makes rocky ledges which form an outer west-trending ridge and then ascends the north slope of the high knob, where the two limbs of the fold seem to join and the syncline appears to end. The axis of the tightly compressed Sugarloaf Mountain syncline evidently has been bent into a horseshoe curve (Fig. 29), and both parts of the bent syncline are overturned to the northwest.

On the geologic map of Frederick County the western part of the bent syncline is shown as continuing southwestward along the crest of the range and joining the syncline that forms the west peak of the mountain and crossing the gorge of Bear Branch to the knob at the north end of Furnace Ridge. The lower hard white quartzite of the formation in that syncline caps the knob at the north end of Furnace Ridge and makes high ledges on the west side of Bear Branch. Similar hard white quartzite ledges on the east side of the stream are offset in strike from those on the west side and may be enclosed in a separate down-fold. These ledges trend almost due north to the top of the western peak of the range, where two prominent parallel ledges of white quartzite trend due north and terminate abruptly in high north-facing cliffs (Pl. 13B). The rock is crushed and veined with quartz and the bedding is not apparent, but the two ledges appear to be in a tightly squeezed syncline. To the east of the cliffs a ledge of current-bedded quartzite, which dips 40° E., is apparently a lower bed of the Sugarloaf Mountain quartzite on the overturned east limb of the syncline (Fig. 29). The Urbana phyllite exposed in Furnace Run is in an anticline between the Furnace Ridge syncline and the Sugarloaf Mountain syncline. The phyllite trends north over the low divide into the headwaters of Bear Branch. It seems probable, therefore, that the Furnace Ridge syncline is a separate fold west of the Sugarloaf Mountain syncline as shown in Figure 29, and that the two synclines do not join as shown on the Frederick County map.

The Sugarloaf Mountain syncline is thus a tight overturned fold which is bent into the shape of a horseshoe that opens southward, and the Urbana phyllite and associated quartzites follow the trend of the syncline. The minor folds in the Urbana phyllite on the north side of the fold pitch south into the syncline; the minor folds in the phyllite on the southeast limb also pitch southeast; minor folds in the Ijamsville phyllite west and northwest of the syncline similarly pitch southeast.

Trend of the Folds and Age of the Folding

The major folds in the crystalline schists of the Piedmont upland are long, linear folds which trend S. 30°–45° W. from the Maryland-Pennsylvania State line to a line which extends S. 45° E. from the vicinity of Union Bridge to southeastern Carroll County. Southwest of this line the trend of the folds turns southward in a broadly curving salient. The trends in the crystalline schists in the southeastern part of the Piedmont upland and in the uplifts of Baltimore gneiss in the schists follow this curving strike. This cross-axis, or Baltimore salient, extends N. 45° W: from Baltimore across the Piedmont upland, crosses the Blue Ridge uplift in South Mountain, Pennsylvania (Fig. 30), and extends northwest across the folds of the Great Valley; hence it is of late Paleozoic age. Williams[90] pointed out this change in trend and noted that the trends in the crystalline belt at the salient have a broad relationship with the flexures of the Appalachian Mountains to the northwest. Mathews[91] noted this sharp bend also in the strike of the anticlines of Baltimore gneiss in the south-

[90] Williams, G. H., The petrography and structure of the Piedmont Plateau in Maryland. Geol. Soc. Amer., Bull. 2, pp. 311–316, 1891.

[91] Mathews, E. B., Anticlinal domes in the Piedmont of Maryland. Johns Hopkins Univ. Circ. N. S., pp. 32–34, 1907.

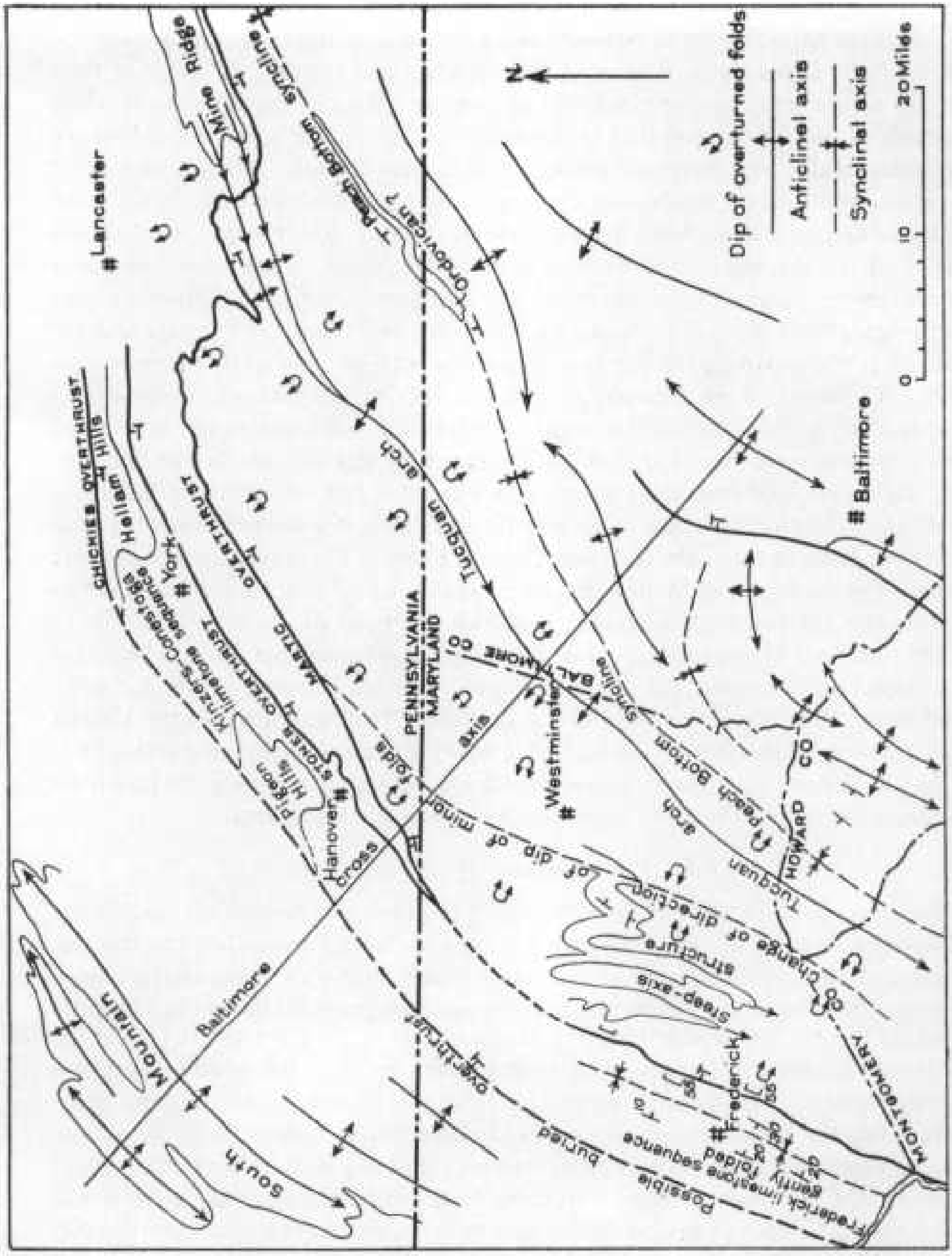

FIG. 30. Major structural axes and faults in the Piedmont Upland in Maryland and adjacent part of Pennsylvania. Shows the relation of the structural features of Frederick and Carroll Counties to those in eastern Maryland and southern Pennsylvania.

eastern part of the Piedmont belt. Although these anticlinal uplifts of Baltimore gneiss are shorter than most folds of Appalachian type elsewhere, he believed that they are of late Paleozoic age because the trend of these anticlines follows the trend of Appalachian folds. Because the trend of the folds in the Piedmont upland and in the Blue Ridge uplift are parallel to the late Paleozoic folds of the Great Valley, all these folds were probably formed in late Paleozoic orogeny.

Interpretation of Steep-Axis Folds

In areas of horizontal or gently dipping fold axes, the beds dip away from the center of the anticline, and on the nose of the fold the older beds in the center of the fold pass successively under younger beds on the margin. At the ends of open synclines the reverse is true. The succession of beds in such folds therefore can be determined at the nose of the folds. From stratigraphic relations in the region of folds with linear trends, it was determined that the Wakefield marble and overlying volcanic rocks underlie the Ijamsville phyllite, Marburg schist, and Wissahickon albite-chlorite schist.

In the area of steep-axis structure, folds in the younger formations (Ijamsville phyllite and Marburg schist) in the region north of New Windsor and Union Bridge pitch south under the Wakefield marble and volcanic rocks which are folded into steep-axis structure. On the south and east sides of the belt of steep-axis structure also, folds in the marble and volcanic rocks pitch south under Ijamsville phyllite and Marburg schist. The succession of these formations at the nose of folds in the direction of the pitch gives no clue to the stratigraphic sequence and hence does not indicate whether the curving folds are anticlinal or synclinal in character.

In the Westminster anticline, Wakefield marble and volcanic rocks are in a series of parallel anticlinal folds which pass southwestward directly into folds with steep fold axes and curving strike. They also involve the Wakefield marble and volcanic rocks which are repeated several times across the strike. It seems probable, therefore, that the steep-axis structure was superimposed on an already folded anticlinal structure and that the marble and volcanic rocks are in anticlinal uplifts with curving strike. Northwest and southeast of the Westminster anticline, synclines of younger rocks pitch southward in the vicinity of the curving anticlinal folds and also are involved in the steep-axis structure. The Sugarloaf Mountain syncline is not only an overturned close fold but its axis of folding seems to have been compressed later into its present curving trend. The steep-axis folds in Carroll and Frederick Counties are at the axis of the Baltimore salient, and northeastward and southwestward pass into folds with nearly horizontal fold axes.

In the east and west Tyrolean Alps, areas of steep-axis structure occur at a northward curve in the alpine strike which is similar to the bend in Appalachian structure at the Baltimore salient. In the east Tyrol the alpine strike is nearly due west; in the vicinity of the Brenner Pass the trend curves southwest and due south. In the east Tyrol east of the Brenner Pass, the Defereger Alps, which lie south of the window of the Hohe Tauern, have steeply pitching folds. In the west Tyrol, west of the change in alpine trend, steeply pitching folds occur also in the Ötztaler and Otler Alps on the southeast side of the Engadine window. These areas of steep-axis structure were described by Sander[92] and Schmidegg.[93] Sander suggested that a possible explanation of vertical fold axes in the above mentioned areas is that the forward movement is checked at some point in its progress and develops at that point a drag that pulls the axis of folding downward toward the focus of restraint or upward around the free-swinging end of the axis. Schmidegg recognized first a folding on horizontal axes; then increased folding with steep-axis structure developed at the bend of the trend in alpine folding.

At the sharp bend in Appalachian strike the curvilinear folds with steep axes in Carroll and Frederick Counties also appear to have been formed by the later compression of an already folded structure.

In the northern and eastern part of Carroll County, east of a line which extends from the Maryland-Pennsylvania State line north of Wentz S. 15° W. through the center of the easterly fold of the belt of steep-axis structure, the folds in the crystalline schists are overturned to the southeast, toward the Tucquan anticline (Fig. 30). West of that line the folds in the crystalline rocks of Carroll and Frederick Counties are overturned in the opposite direction, that is to the northwest. In other words the movement of the rocks of the eastern part of the area is toward the southeast and in the western part toward the northwest. The line along which the overturning changes its direction simulates a synclinal fan fold, but it is not the center of a syncline, for the line transgresses formation boundaries. The divergence of movement of the rocks on opposite sides of this line may have been caused by torsion stresses resulting from the differential movement that produced the Baltimore salient.

Martic Overthrust

The Martic overthrust lies on the west border of the crystalline schists of the Piedmont upland. It extends from Monocacy River in the southern part of Frederick County N. 15° E. to a point two miles east of LeGore, where Triassic sedimentary rocks cover it. The fault lies on the east side of the Frederick syncline. The Ijamsville phyllite of the volcanic series which forms the western edge of the overthrust block is thrust westward over Antietam quartzite of Lower Cambrian age and Frederick limestone of Upper Cambrian age. The fault cuts off the folded structures in these Cambrian rocks. On Monocacy River, 7 miles southeast of Frederick, the contact of Ijamsville phyllite and Frederick limestone is exposed on the south side of the river. The contact surface dips 55° SE. The cleavage in the limestone and in the phyllite dips 55° SE., parallel to the contact. The cleavage in the phyllite has in large part sheared out the close folds in the phyllite. Tension joints healed by quartz are at right angles to the axes of the folds. Linear streaks on the cleavage planes in the Frederick limestone are parallel to the direction of dip of the contact. The Ijamsville phyllite and associated crystalline schists are closely folded, the folds are overturned, and in places the axes dip steeply. This close folding is confined

[92] Sander, Bruno, Tektonik des Schneeberger Gesteinzuges. Geol. Bund., vol. 70, pp. 225–234, 1920, and Erläuterung zur geologishen Karte, Meran-Brixen, 1920.

[93] Schmidegg, Oskar, Neue Ergebnisse in den Südlichen Ötztaler Alpen. Geol. Bund. Verhandl., pp. 84–95, 1933, and Steilachsige Tektonik und Schlingenbau auf der Tiroler Zentralalpen. Geol. Bund., vol. 86, pp. 115–149, 1936.

to the crystalline schists. In marked contrast to the closely folded schists, the Frederick syncline is an open fold with gentle dips. It is clear that the contact of the Ijamsville phyllite and the rocks of the Frederick syncline is marked by a stratigraphic and structural discordance. The writers believe that the contact is an overthrust fault.

The Martic overthrust and the relations of the crystalline schists of that overthrust block to adjacent Lower Paleozoic rocks in Pennsylvania have been described in several reports. The evidence of overthrusting is summarized in a recently published report[94] on the Hanover and York area, Pennsylvania. In the vicinity of Mine Ridge, Lancaster County, Pennsylvania, and southwestward in York County, the crystalline schists in places overlie Harpers phyllite and Vintage dolomite of Lower Cambrian age and Conestoga limestone of Ordovician (?) age, hence the contact is not a conformable one. On the southwest flank of Mine Ridge the schists and underlying Paleozoic rocks have been folded together since overthrusting took place. The pre-Cambrian rocks of the Mine Ridge anticline, and overlying Lower Paleozoic rocks on the flanks, plunge southwest under the albite-chlorite schist of the Wissahickon formation. The albite-chlorite schist is folded into the Tucquan anticline, which is the southwestward continuation of the Mine Ridge anticline. The folds on the northwest side of the Tucquan anticline, in Pennsylvania as well as in Maryland, are overturned southeastward toward the axis of the fold and the rocks on the northwest side of the axis have moved southeastward. The Lower Paleozoic rocks on the north flank of Mine Ridge have the same direction of overturning,[95] hence the southeastward movement is a regional structural feature which occurred in the rocks of both the overthrust and overridden blocks. This folding, which is common to both series, has obscured evidence of overthrusting. In the conclusions stated in a detailed paper on the structure of the rocks in the vicinity of Mine Ridge, Cloos[96] does not seem to be convinced of the existence of the "Martic overthrust" but (pp. 34–35) he describes a five-fold repetition of the stratigraphic sequence in Paleozoic rocks which lies north of the "Martic overthrust" and which he regards as "local thrust sheets" with a lateral transport of several miles. He assumes that these thrust sheets moved northwestward and were later folded, and states that the adjacent Wissahickon schist partakes of this local thrusting.

Because evidence of overthrusting has been obscured by later folding and metamorphism, several writers, including Cloos, have denied or doubted the existence of the Martic overthrust. Cloos for some reason regards as established the series of thrust slices which he has described, although the evidence of the faulting of these slices is just as obscure as that of the Martic overthrust. It is evident that strong pressure directed from the southeast was required to produce the thrust slices. The writers attribute the Martic overthrust to the same type of pressure and conclude that the thrust slices, as described by Cloos, which lie in front of the Martic overthrust, originated in response to the northwestward movement of that overthrust block.

[94] Stose, A. J., and Stose, G. W., op. cit. U. S. Geol. Surv., Prof. Paper 240, pp. 71–73, 1944.

[95] Stose, A. J., and Stose, G. W., Idem, p. 69, fig. 27, 1944.

[96] Cloos, Ernst, Op. cit., Geol. Soc. Am., Special paper no. 35, p. 191, 1941.

In Pennsylvania the trace of the Martic overthrust is sinuous because the dip of the fault is low and the rocks of the overthrust and overridden blocks have been folded together since overthrusting. The fault east of the Frederick syncline is straight and dips rather steeply (55°) southeast, parallel to the contact and to the cleavage in the overridden Frederick limestone. It seems probable, therefore, that the present fault east of the Frederick syncline was produced by a recurrent movement on the Martic overthrust during a late phase of deformation when the steeply dipping transverse cleavage was formed in the crystalline schists, and that this recurrent movement carried the crystalline schists of the Martic overthrust block farther northwestward until it now overlies the eastern part of the Frederick syncline. In York County, Pennsylvania,[97] the Martic overthrust block lies southeast of the Stoners overthrust block which separates the Martic block from the Hanover and York Valleys. These valleys carry a limestone sequence partly equivalent to that in the Frederick syncline. It is believed that in Maryland, the Martic overthrust block moved so far westward that it has overridden the Stoners overthrust block and lies over the limestones of Frederick syncline, which are in large part stratigraphically equivalent to the limestones in the Hanover and York Valleys in Pennsylvania.

TRIASSIC STRUCTURAL FEATURES

The Triassic rocks were deposited after the diastrophism that folded and thrust faulted the Paleozoic and older rocks, and therefore they do not possess these structures. The Triassic rocks in Frederick and Carroll Counties have been tilted gently northwestward and broken by normal faults. The major fault is the Triassic border fault which bounds the Triassic rocks on the west side and has down-dropped them in respect to the Catoctin Mountain-Blue Ridge anticlinorium on the west. Faults within the Triassic rocks have offset the beds, and faults at the eastern border of the Triassic affect both the Triassic rocks and underlying older rocks.

The dip of the Triassic sedimentary rocks averages 25° NW. and the strike is in general northeast. The northwest dip is due in part to northwestward overlap of beds during deposition but also to down-faulting on the west side of the basin and consequent westward tilting of the block. The strike bends locally, forming two gentle synclines. In the northern syncline the trend of the rocks is parallel to the diabase sills north of Emmitsburg, and the beds dip northeast, north, and northwest under the sills. The other syncline lies southwest of Motters, where the beds trend northward and then N. 20° W. The synclines are separated by a diagonal fault that trends southeast from the Triassic border fault north of Mount St. Marys and passes through Motters. Northeast of Appolds, the beds bend sharply south and dip west near the fault. Evidently these local folds were produced by the displacement of the fault blocks.

The Triassic rocks are bounded on their west side by a series of longitudinal straight normal faults, called the Triassic border fault, along which the Triassic rocks have been down-faulted several hundred feet. The Triassic border fault enters Frederick County from Pennsylvania on the southwest side of Toms Creek Valley, and for about two miles trends southeast and then due south for a mile to a point near

[97] Stose, A. J., and Stose, G. W., op. cit., U. S. Geol. Surv., Prof. paper 240, 1944.

Mount St. Marys. Here it bends southwestward and extends in that direction to a point near Catoctin. South of Catoctin to Potomac River the strike of the fault is more southerly and in places almost due south. From the sharp bend in the border fault at a point one mile north of Mount St. Marys, a minor fault continues southeastward along the same fracture plane into Triassic rocks, passes through Motters, and ends on Monocacy River near the mouth of Double Pipe Creek, where it is cut off by an east trending normal fault. The effects of this diagonal fault on the Triassic rocks was mentioned above.

For several miles east and south of Thurmont and just south of Mount St. Marys, Paleozoic limestone is exposed between the west edge of the Gettysburg shale and the Triassic border fault. Faults are not shown on the Frederick County map at the contact of the Triassic shale and the limestone. This contact in the area near Thurmont is concealed by a thick cover of Quaternary gravel. The nearly straight trend of the contact, where visible, suggests a normal fault, parallel to the border fault, which has down-dropped the Triassic rocks to the east (Fig. 18). A limestone conglomerate at the contact east of Roddy was probably derived from limestone uplifted west of the fault. If such was the case, the movement on the fault began before the close of deposition of the Triassic rocks. It is probable that the area of limestone south of Mount St. Marys also is bounded by normal faults, as is suggested in figure 18.

Northwest of Lewistown an area of Paleozoic limestone within the Triassic is brought to the surface between two intersecting diagonal faults. The limestone was raised along a northeast-trending fault that lies on its southeast side. On its northwest side the limestone is normally overlain by northwest-dipping New Oxford formation, which has a limestone conglomerate locally at its base. The Triassic rocks and the underlying Paleozoic rocks are cut off across their strike by a northwest-trending normal fault. This fault also offsets the older rocks in the foothills of Catoctin Mountain and the Triassic border fault and its parallel companion fault, and is therefore somewhat younger than those faults.

Northwest of Frederick and east of the Triassic border fault, a northwest-trending normal fault has down-dropped the Triassic rocks on the north and has brought the limestone floor to the surface for a distance of two miles to the southwest. South of U. S. Highway 40, the Triassic rocks again lie east of the border fault. A northeast-trending fault offsets the Triassic border fault near Braddock and the rocks in the Catoctin syncline farther west, and cuts off the northwest-trending fault just described.

From Mount St. Marys southward, a normal fault lies west of, and more-or-less parallel to, the Triassic border fault. Its down-throw, like that of the border fault, is on its east side. The fault lies east of the main Catoctin Mountain syncline. From a point near Catoctin southwestward, the narrow block between the parallel faults contains east-dipping Harpers phyllite, Antietam quartzite, and Tomstown dolomite. This block may be a down-dropped part of the Catoctin Mountain syncline. North of Catoctin, in the narrow belt between the two faults, Frederick limestone overlies Lower Cambrian quartzose rocks. The fault block containing Frederick limestone is not regarded as a part of the Catoctin Mountain syncline but as part of the Chickies overthrust block in a down-dropped position. The nearly parallel faults along the east foot of Catoctin Mountain, therefore, have stepped-down the rocks to the east in a series of stratigraphically unrelated fault blocks.

The Triassic border fault and the parallel step fault to the west are later than the deposition of the Triassic rocks, and not only displace the Triassic rocks but also displace and offset the late Paleozoic structures in the older rocks. The diagonal faults offset the Triassic border faults and are apparently a last stage of post-Triassic faulting.

The eastern border of the Triassic rocks in northern Carroll County and at points 10 miles to the southwest near the Carroll-Frederick County line is offset by a series of parallel northeast-trending normal faults. In the vicinity of Markers Mill in northern Carroll County, three normal faults displace the basal conglomerate of the New Oxford formation. The faults trend northeast; two of them are parallel, and the northern fault trends more northerly. The down-throw on these faults is on the southeast side, and the New Oxford formation in each fault block is offset to the northeast. The beds of the basal conglomerate trend against the faults. These faults extend into, and displace also, the crystalline rocks which underlie the New Oxford formation. Two northeast-trending faults produce similar offsets of the base of the New Oxford formation and the underlying crystalline rocks near the Carroll-Frederick County line in the region west of Union Bridge. The fault that extends through Keymar offsets the New Oxford formation 3 miles to the southwest. Along the fault that lies ½ mile east of Goodintent School, the base of the New Oxford formation is bent into a gentle fold. The basal Triassic rocks and the underlying older rocks are offset to a small extent by north-trending faults at a point 3 miles west of Union Bridge and at a point 5 miles north of Frederick.

Two outliers of Triassic rocks lie east of the main belt. In the northern one, at Arters Mill, basal Triassic conglomerate caps a small hill and is down-dropped east of a north-trending normal fault. The conglomerate rests on Marburg schist, and is faulted against Silver Run limestone, which underlies the schist. Northeast of Tyrone an area of New Oxford formation 2½ miles long is down-faulted on its northwest side, and the beds dip northwest toward the fault. The outlier is 1 mile east of the main Triassic area. At the southwest end, the Triassic outlier is cut off by a nearly west-trending fault, which extends westward into the main Triassic area and at Fairview School offsets westward the basal beds of the Triassic rocks a distance of one mile.

At the south edge of Frederick County a triangular block of New Oxford formation lies east of a northeast-trending normal fault which crosses Monocacy River near its mouth. There the base of the formation is displaced 4 miles to the east. Two parallel faults to the west cut the Antietam quartzite and Frederick limestone, but are not known to break the Triassic rocks to the south because the outcrops of those rocks are concealed by the alluvium in the Potomac River floodplain, but these faults are undoubtedly also of Triassic age. To the south, southeast of Beallsville, Montgomery County, other faults, with down-drop on the southeast, have displaced the Triassic rocks in repeated blocks and have widened the belt of Triassic rocks.

Straight, north-trending faults which occur in pre-Triassic rocks are probably also Triassic in age. Two north-trending parallel faults at and north of Jefferson, and another straight, northeast-trending fault, which cuts diagonally across the structure of Paleozoic limestones west of Buckeystown, appear to be normal faults of Triassic type.

It has been stated that most of the Triassic diabase dikes have a northerly trend, more-or-less parallel with the normal faults just described. The dikes follow joint planes or minor breaks produced by the same forces that caused the normal faults. Where the diabase dike at LeGore passes south out of the New Oxford formation into the Grove limestone, the New Oxford formation is offset and the dike follows a north-trending fault which produced the offset.

The Triassic period was characterized by the sinking of the surface of the land into a longitudinal basin, which trended northeastward across northern Virginia, Maryland, and southern Pennsylvania, in which the Triassic sediments were deposited. Normal faulting on nearly vertical breaks that accompanied this sinking, and the gravitational settling of fault blocks, indicate a state of tension in the rocks. The welling up of diabase magma into vertical fissures and along bedding planes at this time also indicates a lowering of the pressure in the rocks at depth beneath the basin and the liquefaction of deep-seated basaltic rocks due to the reduction of pressure.

MINERAL RESOURCES OF CARROLL AND FREDERICK COUNTIES

BY

JOSEPH T. SINGEWALD, JR.

Mineral products now being produced in Carroll and Frederick Counties are lime, cement, crushed stone, clay, soapstone and flint (quartz). Other mineral products that have been produced are building and ornamental stones, building sand, roofing granules, feldspar, iron ore, copper ore and lead ores. Occurrences of zinc ore, barite, and gold have been prospected.

Limestone, Lime and Cement

Limestone is quarried and burned to lime, used in the manufacture of cement, pulverized for agricultural use, crushed for road material and concrete, and used as a building stone.

Limestone underlies the whole of the Frederick Valley lowland. Smaller areas occur in the western part of the Triassic upland and in the Piedmont upland. The limestones of Frederick County are the Grove and Frederick limestones, the Tomstown dolomite, the Wakefield marble, the limestone conglomerate at the base of the Triassic New Oxford formation, and the marble associated with the Catoctin metabasalt. The limestones of Carroll County are the Wakefield marble, the Silver Run limestone and the Cockeysville marble. The areal distribution of the limestones is shown on the geologic maps of Carroll and Frederick Counties. The areal distribution of the limestones and marbles in eastern Carroll County is shown also in Figure 4.

FREDERICK COUNTY

Grove Limestone

Most of the operating limestone quarries in Frederick County are in the Grove limestone, and most of the abandoned quarries were in this limestone. Though described geologically as a thick-bedded pure limestone, the strata included in the Grove limestone show a wide range in chemical composition. Only some beds are pure enough to meet the specifications for agricultural lime. The limestone generally runs too high in magnesia to produce a high calcium lime that meets metallurgical and chemical lime specifications even when the content in insoluble impurities meets these specifications.

Thirty-two analyses from quarries in the Grove limestone cited in the report on the Limestones of Maryland[1] show the following range in composition:

[1] Mathews, E. B., and Grasty, J. S., Maryland Geological Survey, vol. 8, 1909, p. 396.

	Minimum	*Maximum*	*Average*
SiO_2	0.17	13.94	4.51
Al_2O_3	0.44	7.08	1.86
Fe_2O_3	0.12	1.57	0.57
R_2O_3	0.14	10.92	2.58
CaO	33.97	55.72	47.77
MgO	0.14	17.11	3.72
Ignition loss	35.65	46.41	41.29
$CaCO_3$	60.60	98.70	83.86

Samples of two groups of purer beds in the Grove limestone west of McAleer show the following composition:

Thickness	*Minimum*		*Maximum*		*Average*	
feet	*SiO_2*	*MgO*	*SiO_2*	*MgO*	*SiO_2*	*MgO*
400	1.75	0.40	4.05	3.06	3.15	1.68
200	1.77	0.80	6.16	5.55	3.71	1.94

Near Limekiln, twenty two samples across an outcrop width of 2500 feet show the following range in composition:

	Minimum	*Maximum*	*Average*
SiO_2	6.90	21.36	11.85
Al_2O_3	0.28	0.85	0.42
Fe_2O_3	0.27	0.81	0.48
CaO	30.25	48.97	39.30
MgO	0.29	18.14	8.63
Ignition loss	—	—	40.39

The analyses of a section across the beds of the quarry of the LeGore Lime Company from west to east obtained from the Company show the following composition:

Thickness feet		*SiO_2*	*Al_2O_3*	*Fe_2O_3*	*CaO*	*MgO*
34.2		1.16	0.59	0.11	54.69	0.65
32.4		0.74	0.16	0.11	55.42	0.58
45.9		6.74	0.96	0.55	45.74	5.11
18.0		18.12	1.77	0.95	35.81	7.57
27.0		0.02	0.03	0.05	55.55	0.47
27.0		5.66	0.84	0.48	49.90	1.88
Total...184.5	Average	4.62	0.68	0.35	50.17	2.58

In this quarry are 66 feet of beds that average:

SiO_2	0.96
Al_2O_3	0.38
Fe_2O_3	0.11
CaO	55.05
MgO	0.62

These 66 feet of beds meet the specifications for metallurgical and chemical high calcium limestone.

A bed of massive limestone in the M. J. Grove Lime Company quarry at Frederick has the composition:

Insoluble	0.60
$Al_2O_3 + Fe_2O_3$	0.24
CaO	52.12
MgO	2.89
Ignition loss	44.15

This stone is very low in impurities but too high in magnesia to meet specifications for high grade, high calcium limestone.

That the Grove limestone includes beds that are low in silica and some that are low in both silica and magnesia is shown also by the following analyses of lump lime samples published in the State Inspection and Regulatory Service Control Series Quarterly:[2]

Operator	*CaO*	*MgO*	*Carbonates*	*Insoluble*
LeGore Lime Co., LeGore	92.20	3.47	0.93	0.61
S. W. Barrick & Sons, LeGore	88.80	0.84	5.57	1.19
S. W. Barrick & Son, LeGore	94.05	0.90	3.95	0.78
Stoner and Powell, Fountain Rock	93.15	1.81	2.13	0.98
Stoner and Powell, Fountain Rock	83.60	8.26	1.59	0.48
Shank and Etzler, Frederick	59.45	32.97	11.68	0.61
Shank and Etzler, Frederick	60.15	37.12	3.07	0.15
M. J. Grove Lime Co., Frederick	80.85	13.65	1.50	1.38
M. J. Grove Lime Co., Frederick	78.80	14.19	9.86	1.42

These analyses of lump lime show that the Grove limestone ranges from a stone low in magnesia to stone that is almost a dolomite.

The preceding analyses show that much of the Grove limestone consists of beds that are too impure to produce even an acceptable quality of agricultural lime. On the other hand there are groups of beds ranging up to 400 feet in thickness that average pure enough to produce an acceptable quality of agricultural lime. Within these groups of beds are wide variations in the percentages of impurities and of magnesia. The lime producers have done little selective quarrying, so that there have been considerable variations in the chemical composition of the lime produced at the same plant. The quality and uniformity of the Frederick Valley lime could be greatly improved if more attention were paid to the variations in composition of the beds of limestone in the quarries and the kiln stone selected accordingly, the less pure beds being kept out of the kiln stone and utilized for crushed stone. There are also thicknesses of several tens of feet of very pure stone that could be worked separately in the quarries to produce a very high grade lime with a very low percentage of impurities. Though most of this pure stone contains too much magnesia to serve as high calcium limestone, some of it is low enough in magnesia also to be suitable for the production of high calcium limestone and high calcium lime. Selective quarrying of these beds would permit the sale of the product in other than the agricultural lime market.

The producers have been content to serve only the agricultural ground limestone and lime market, so that they have had little need to utilize the more modern types of kilns and all of the lime produced in Frederick County is still burned in the old style pot or mixed feed kilns.

[2] No. 191, August, 1944, pp. 104–5, and no. 193, January, 1945, p. 78.

Wakefield Marble

Narrow belts of Wakefield marble occur in eastern Frederick County, but only two quarries are now in operation, the Lehigh Portland Cement Company quarry south of Union Bridge, and the Farmers Cooperative Association quarry near New London.

The report on the Limestones of Maryland[3] cites 15 analyses of the Wakefield marble, which show the following range in composition:

	Minimum	*Maximum*	*Average*
SiO_2	0.31	5.02	2.30
Al_2O_3	0.04	3.00	0.97
Fe_2O_3	0.02	0.64	0.21
R_2O_3	0.09	3.15	1.01
CaO	46.00	55.27	52.28
MgO	0.33	5.29	1.37
Ignition loss	41.64	44.34	42.84
$CaCO_3$	81.90	98.70	93.16

Six of these analyses are from the quarry of the Lehigh Portland Cement Company. The average of five of these analyses, omitting one high magnesia analysis, is:

	Average five analyses
SiO_2	2.10
R_2O_3	0.82
CaO	54.01
MgO	0.56
Ignition loss	42.90
$CaCO_3$	96.42

The preceding analyses are all in the vicinity of Union Bridge. An analysis of pulverized limestone from the Farmers Cooperative Association quarry near New London is:[4]

CaO	44.75
MgO	5.53
Insoluble	8.23

The Wakefield marble varies greatly in silica and magnesia content, but it includes limestone relatively low in silica and quite low in magnesia. By proper choice of location and selective quarrying a high grade high calcium limestone can be produced. However, the outcrop areas of Wakefield marble are narrow and are generally in the valley floors, and except for the Union Bridge area are long distances from railroad transportation. The Wakefield marble will support only small operations for local consumption.

Production

	Limestone tons	*Quick lime tons*	*Hydrated lime tons*
1944	240,000*	34,895	26,227
1943	173,824	36,200	34,880
1942	128,321	26,441	28,767

* Estimated.

[3] Loc. cit., p. 378.

[4] State Inspection and Regulatory Service, Control Series Quarterly, No. 191, August, 1944, page 108.

Operating Plants

Many of the quarries that have operated in Frederick County are described in the report on the Limestones of Maryland published by the Maryland Geological Survey in 1909.

The present operating plants are:

Limestone	*Operator*	*Location*
Grove	LeGore Lime Company	LeGore
Grove	S. W. Barrick and Sons, Inc.	LeGore
Grove	Stoner and Powell	Fountain Rock
Grove	Shank and Etzler Lime Co.	Frederick
Grove	M. J. Grove Lime Co., Inc.	Frederick
Wakefield Marble	Farmers Cooperative Assn., Inc.	New London
Wakefield Marble	Lehigh Portland Cement Co.	Union Bridge
(Washington County)	Everett V. Moser	Bolivar

LeGore Lime Company.—This plant is located on the east side of the Pennsylvania Railroad at LeGore.

In Figure 13 are a plan and sections of the beds at the two ends of the quarry. Plate 17B shows the face at the north end. The beds are overturned with a steep easterly dip. An east-west fault across the quarry has resulted in bringing the lower impure beds of the Grove limestone into the south quarry face which is worked only for crushed stone. Higher, purer beds are exposed in the north face. At the west end of the north face are nearly 70 feet of beds said to average 0.96% silica and 0.62% magnesia. The footwall portion of these beds is white to light dove gray limestone and the hanging wall portion a darker dove gray limestone. Near the hanging wall end of the face are 27 feet of dark gray limestone said to average 0.02% silica and 0.47% magnesia. The rest of the beds in this face are blue limestone with higher silica and magnesia contents. Complete analyses of the beds in the north face as reported by the company are given on a preceding page. Analyses of the limestone in this quarry reported in the Limestones of Maryland are:[5]

	No. 16	*No. 18*	*No. 19*	*No. 20*	*No. 21*
Silica	4.21	4.55	2.85	8.51	2.34
Alumina	1.18	1.61	0.44	2.77	0.92
Iron oxide			0.71	0.78	
Lime	52.76	49.40	54.00	38.72	51.80
Magnesia	0.75	3.25	0.49	6.45	2.43
Ignition loss	41.46	41.68	42.25	40.07	42.75

No. 16.—Dove to light gray limestone.
No. 18.—Bulk sample of 150 feet nearest the railroad.
No. 19.—White to light dove gray limestone.
No. 20.—Blue gray limestone.
No. 21.—Gray limestone.

Operations were started in 1861. The property comprises about 200 acres. The kilns are mixed feed kilns with a capacity of 100 tons of lime daily. Raymond mills and a Shaffer Hydrator produce 50 tons of hydrated lime daily. The lime is sold

[5] Loc. cit., p. 384.

principally to the agricultural trade, and a storage capacity of 8,000 tons is provided to take care of the seasonal demand when shipments increase to 600 tons per day. Crushed stone and agricultural limestone are also produced. The plant is operated with electric power.

S. W. Barrick and Sons, Inc.—This plant is on the west side of the Pennsylvania Railroad at LeGore.

The quarry is on the west limb of the overturned syncline on the east limb of which the LeGore quarry is situated. The dip on the footwall is 67° and steepens on the hanging wall. The section across the north quarry face from east to west is:

Length along face feet	*Description*
100	Light to dark gray limestone
70	White limestone with deep dirt pockets
30	Light gray limestone
70	Dark gray limestone with abundance of sand grains in lower part

A lower level is being developed in the white limestone in the quarry floor at the foot of the incline. Analyses of this stone reported by the Company are:

Insoluble matter	1.77	1.81
Alumina and ferric oxide	0.47	0.45
Calcium carbonate	78.26	79.86
Magnesium carbonate	19.03	17.84

The strike of the beds carries the white limestone under the lime kilns toward the south, so that future extension of the quarry must be toward the north.

A bulk sample of the beds in this quarry reported in the Limestones of Maryland showed the following average composition:[6]

Silica	4.63
Alumina and iron oxide	1.13
Lime	49.45
Magnesia	3.01
Ignition loss	41.79

The plant was established in 1874 by Samuel W. Barrick, who erected 3 pot kilns and sold lump lime by the bushel to local farmers. The plant was gradually expanded to 20 pot kilns and shipments made by rail in car lots into more distant territory. Machinery was installed to grind and hydrate the lump lime as production increased. The company is a closed corporation owned entirely by the descendents of the founder.

The stone is loaded in the quarry by steam shovel and by hand. Coke is used as fuel in the kilns. The lump lime drawn from the kilns is transported to the storage bin by trucks. The capacity of the kilns is 110 tons daily. From the storage bin the lime is fed to a belt conveyor and carried successively to a New Holland roller mill and a Stedman hammer mill. The pulverized lime then goes either to the hydrator or to a storage tank equipped with a bagging machine. Storage space

[6] Loc. cit., p. 385.

with a capacity of 5,000 tons of quick lime and hydrated lime is available to stock production during the off season.

During the past few years a large portion of the output has been handled by the Agricultural Conservation Association in farm building program.

The company has adhered to a policy of producing agricultural lime exclusively until recently when stone crushing facilities were added.

Stoner and Powell.—This plant is on the north side of the Pennsylvania Railroad at Fountain Rock.

The beds in this quarry dip 27° west. A face 100 feet wide is being worked for kiln stone. To the east of these more massive beds is thinner bedded, very fine-grained, hard, dark limestone used only for crushed stone. The kiln stone is lighter in color and softer. Analyses of 28 feet of gray to dove colored stone and of 20 feet of overlying blue stone reported in the Limestones of Maryland are:[7]

	Gray to dove	*Blue*
Silica	3.62	6.65
Alumina	0.93	1.30
Iron oxide	0.30	0.51
Lime	46.41	47.99
Magnesia	5.82	3.09
Ignition loss	42.59	40.47

The plant consists of 8 mixed feed kilns. Hydrate is slaked by hand on the floor of the hydrating building. There is also a small stone crushing plant operated by a tractor.

Shank and Etzler Lime Co.—This plant is located at the east edge of Frederick adjacent to the west end of the Fair Grounds.

The quarry has been worked on both sides of a road that runs parallel to the face. The height of the face is about 20 feet. The beds on the west side of the road dip steeply to the east, and those on the east side of the road have a flat easterly dip. Present production is from the east face. The stone is a gray-white crystalline limestone. Some of the beds contain quartz grains.

An analysis of a bulk sample reported in the Limestones of Maryland is:[8]

Silica	0.98
Alumina	0.58
Iron oxide	0.61
Lime	34.02
Magnesia	17.11
Ignition loss	46.41

The plant consists of 6 mixed feed kilns fired with coke, a pulverizer, and a screw conveyor for hydration. Lump, pulverized, and hydrated lime are produced for agricultural use only.

M. J. Grove Lime Company, Inc.—The plant is located a half mile beyond the southeastern city limits of Frederick.

[7] Loc. cit., p. 387.
[8] Loc. cit., p. 396.

A vertical cross section of the beds in this quarry is shown in Figure 14. A thickness of 100 feet of purer limestone beds is underlain and overlain by less pure beds with an abundance of quartz grains. In some beds the quartz is so abundant that the rock is almost a sandstone with a carbonate matrix. Sand grains are also abundant in some of the beds in the 100 feet of purer limestone.

The quarry now has a lower level entirely within the 100 feet of purer beds (Plate 17A). At the west end of the lower level face is very pure massive limestone, represented by sample A. At the east end of this face are 40 feet of beds that are slightly sandy but with varying amounts of sand, represented by sample B. Between the beds of samples A and B some of the beds are very sandy. The dip at the west end of this face is 35° east and at the east end is 25° east. On the upper level on the east side of the quarry the dip is low to the west.

The analyses of samples A and B are:

	A	*B*
Insoluble	0.60	10.70
Alumina and iron oxide	0.24	0.60
Calcium carbonate	93.08	79.83
Magnesium carbonate	6.08	8.87

The wide range in composition of the beds in this quarry is illustrated even more strikingly by two analyses reported in the Limestones of Maryland:[9]

	No. 38	*No. 39*
Silica	23.86	2.47
Alumina and iron oxide	1.42	0.77
Lime	36.65	43.64
Magnesia	5.10	9.50
Ignition loss	33.46	43.97

Drilling is done with churn drills and the stone loaded on Dumptors by mechanical shovels which deliver the stone to a crusher located in the quarry. The crushed stone is carried to the screening plant on a belt conveyor. The crushing plant has a capacity of 125 tons per hour. The kiln stone is burned in 12 pot kilns that have a capacity of about 100 tons per day. Lump, ground, and hydrated lime are produced. Both agricultural and mason's lime are marketed. Crushed stone and concrete and cinder block are also produced. The concrete and cinder block plant was installed in 1925 to use the fines from the crushed stone plant. This plant has been expanded to an output of 800,000 units per year. The size of the blocks is 8 by 8 by 16 inches.

Farmers Cooperative Association, Inc.—The operation is located ¾ mile southeast of New London.

The quarry is in a narrow zone of Wakefield marble with a steep southerly dip along the base of the hill slope on the south side of Bens Branch. The marble occurs in lenticular beds within volcanic schists. The maximum width of the outcrop at the quarry site is nearly 200 feet. About 300 feet east of the plant, the marble is

[9] Loc. cit., p. 391.

cut out by the enclosing schists. Directly west of the plant the width of the outcrop is about 150 feet. A short distance further west the outcrop is considerably wider.

The marble varies from a white sugary rather pure marble to a deep red and locally greenish limestone. Analyses of the pulverized limestone in the State Inspection and Regulatory Service Control Series Quarterly are:[10]

CaO	44.75	38.45	37.80
MgO	5.53	9.18	9.62
Insoluble	8.23	11.15	11.32

The limestone is crushed to pass a 20 mesh screen in a pulverizing mill equipped with large hammer mills and a roller mill. Deliveries are made direct to farmers in Frederick, Carroll, Howard, and Montgomery counties in bulk, in bags, or spread by truck direct to the field. The plant has been operating since 1941.

Lehigh Portland Cement Company.—The cement plant is in Carroll County on the north side of Sams Creek at the southern end of Union Bridge, and the quarry is on the opposite side of Sams Creek in Frederick County.

The quarry is in a north-south trending zone of Wakefield marble bounded on each side by metabasalt schists. It has been extended southward a distance of about $\frac{3}{4}$ mile. The associated schists are quarried to furnish the argillaceous ingredient of the cement mix. The face varies in height from 45 to 70 feet. The $CaCO_3$ content of the limestone averages about 96%, except for a portion that runs high in silica and another portion that runs high in magnesia. Seven analyses of the limestone reported in the Limestones of Maryland[11] showed the following range in composition:

	Minimum	*Maximum*	*Average*
SiO_2	0.28	6.40	2.37
$Al_2O_3 + Fe_2O_3$	0.20	0.62	0.39
CaO	51.04	54.89	53.41
MgO	0.46	1.34	0.90
Ignition loss	40.84	44.27	42.97
$CaCO_3$	91.14	98.01	95.37

Three analyses of the schist cited in the same report are:

	Minimum	*Maximum*	*Average*
SiO_2	52.74	58.00	55.09
Al_2O_3	22.28	24.24	23.32
Fe_2O_3	8.40	11.30	9.83
CaO	0.20	0.85	0.49
MgO	1.78	2.33	2.06

The silica needs for the cement mix are supplied from weathered quartzite, called sand rock, of the Glen Arm series south of the Union Bridge-Johnsville road, about $2\frac{1}{2}$ miles southwest of Union Bridge.

Representative analyses of the three raw materials as now being produced are reported to be:

[10] No. 191, August, 1944, p. 108; No. 193, January, 1945, p. 81.
[11] Loc. cit., p. 370.

	Limestone	*Shale*	*Sand rock*
SiO_2	1.10	54.40	94.04
$Al_2O_3 + Fe_2O_3$	0.40	32.22	2.54
CaO	54.80	0.16	0.23
MgO	0.87	2.44	0.07
Ignition loss	43.05	4.79	1.07
	100.22	94.01	97.95

The plant was built in 1910 and 1911 and operated by the Tidewater Portland Cement Company. It was purchased in 1925 by the Lehigh Portland Cement Company. It was virtually rebuilt during the years 1938 to 1941 (Plate 18A).

The stone is loaded in the quarry by electric shovels and hauled to the plant crusher by Diesel-electric locomotives. It is crushed by means of a roll crusher followed by a hammer mill in closed circuit with a vibrating screen. The crushed materials are distributed to covered storage bins adjacent to the crushing plant by an overhead crane.

The raw materials are dried and ground in one operation. The pulverized product is pumped to blending bins from which it is pumped to the kiln feed bins. The five kilns are fired with pulverized Pittsburg slack coal supplied by unit pulverizers. The clinker is stored in a covered storage space. It is ground in a two-stage operation using a ring roll mill for the preliminary grinding and tube mills and air separators for the final stage. The finished cement is pumped to the stock house. Both raw and finish mills are housed in one building and operated by a single crew.

A modern waste heat power plant supplies the entire power requirements when the plant is in operation. Purchased power is used only for idle periods. Dust collectors are installed wherever escape of dust would be a hazard or nuisance. Filter type collectors are used where temperatures permit. Mechanical collectors arrest most of the kiln dust which escapes from the waste heat boilers.

The plant is equipped to manufacture all types of portland cement regularly produced by the company. There is storage capacity for 66,000 barrels of clinker and 90,000 barrels of cement.

Everett V. Moser.—This plant is at Bolivar on the west side of the road to Mt. Tabor Church. It consists of 4 pot kilns and produces only lump lime and ground quick lime. The stone is hauled in trucks from a quarry near Keedysville in Washington County.

Analyses of the lump lime and ground burnt lime reported by the State Inspection and Regulatory Service[12] are:

	Lump	*Ground*
CaO	92.40	84.15
MgO	3.40	2.15
Insoluble	0.80	1.86

CARROLL COUNTY

Limestone underlies many of the valleys of northeastern and north central Carroll County. All of the Carroll County limestones are mapped as Cockeysville marble

[12] Control Series Quarterly, No. 191, August, 1944, p. 105.

on the Carroll County geologic map. In the portion of north central Carroll County included in the Frederick County geologic map they are mapped as Wakefield marble and as Silver Run limestone. On the revised geologic map of northeastern Carroll County, Figure 4, the limestones are all shown as Wakefield marble.

The exposures in the northeastern part of the country are in long narrow northeastward trending valleys and not suitable for large quarrying operations. Larger areas providing more satisfactory quarry sites are in north central Carroll County between Westminster and Union Bridge.

Fifteen analyses from north central Carroll County reported in the Limestones of Maryland show the following range in composition:[13]

	Minimum	*Maximum*	*Average*
SiO_2	0.31	8.06	2.23
Al_2O_3	0.56	3.80	1.48
Fe_2O_3	0.38	1.68	0.66
R_2O_3	0.39	5.48	1.48
CaO	34.16	54.82	45.94
MgO	0.10	16.27	6.55
Ignition loss	37.74	46.26	43.47
$CaCO_3$	62.7	98.0	81.94

There is considerable range in the silica and magnesia content of these limestones. Three of the analyses show under 1% silica but only one shows under 1% magnesia. The latter contains over 2% silica. Most of the occurrences are suitable, therefore, only for the production of crushed stone, agricultural lime products, and mason's lime.

Production

Despite the fact that many of the limestone areas of Carroll County are crossed by the Western Maryland Railroad between Westminster and Union Bridge and are accessible to the Western Maryland Railroad in the northeastern corner of the County, no limestone is being produced in Carroll County at present. The former stone quarries and lime plants served only the local market and were small operations located without regard to the railroad.

A number of the old quarries are described in the report on the Limestones of Maryland. The last operation in Carroll County was at the Hyde Quarry of John S. Hyde, ½ mile north of Wakefield. Quarrying ceased here in 1942. Two stone lime kilns and a small crushing plant are still standing, but the quarry is full of water. A cement block plant using screenings trucked from Hanover, Pennsylvania, is now being operated at the site. The quarry was a pit quarry worked along the side of the hill on the west side of the valley of Little Pipe Creek.

BUILDING AND ORNAMENTAL STONE

Wakefield Marble

The Wakefield marble of Carroll County and eastern Frederick County has furnished samples of unsurpassed variety and beauty. Samples exhibited at the Cen-

[13] Loc. cit., p. 378.

tennial Exposition in Philadelphia in 1876 included "deep red", "dark red veined with white", "salmon colored", lavender veined", "undulate pink and white", and "ruby". Many other varieties can be obtained. Years ago beautiful slabs were utilized for altar fronts and interior decorations.

A serious drawback to utilizing this marble as a building stone is the irregular distribution of the colors. The variations in color are so frequent and uncertain, that it would be extremely difficult for a quarry to fill a moderately large order with material like a given sample. The jointing also is not trustworthy, and the rock tends to break down into thick angular blocks rarely more than 8 cubic feet in size, so that rocks of the size, shape, and quantity for building purposes are difficultly obtainable. Part of the difficulty in quarrying this marble was due to the crude extraction methods that were used when attempts were made to exploit these marbles years ago. Shooting was resorted to in order to make extraction easier, instead of working carefully with channeling machines. Whatever economic possibilities these marbles have are probably limited to their use as ornamental stone for interior decorations in the form of mosaics and mantels.

The largest operation for ornamental stone was that of The Maryland Cremo Marble Company, on the Rhinehart property, 1¾ miles southwest of Union Bridge. The quarry was opened about 1905 and equipped with Sullivan channelers. The marble here has a faint creamish tint, is fine-grained, and takes a beautiful polish. The workable thickness is a little over 220 feet. Six analyses of the marble range in calcium carbonate content from 84.8 to 96.2 per cent.[14] This operation has long since been abandoned and all of the equipment has been removed.

Potomac Marble[15]

The limestone conglomerate at the base of the Triassic New Oxford formation has been used for ornamental stone under the names "Potomac marble", "Calico marble", and "Potomac breccia". It is the only true conglomerate or breccia marble ever utilized to any extent in the United States.

It has been most extensively quarried along the eastern slope of the Blue Ridge in the vicinity of Point of Rocks and Washington Junction in Frederick County. The individual quarries were small and production was intermittent. The marble occurs in lenticular bodies ranging from 1 foot to at least 500 feet in thickness. Along the strike they grade into sandstone or thin out to a feather edge. The rock is made up of pebbles of limestone which sometimes reach a foot in diameter but usually average about two to three inches. The fragments are both well rounded and angular and range in color from gray to blue and dark blue. Occasional pebbles consist of quartz, chloritic schist, and white marble. The pebbles are embedded in a red calcareous matrix with more or less sand. The bedding is irregular and of little aid in quarrying the rock. Jointing is also relatively subordinate. Rupturing in quarrying is determined largely by differences in cohesion between parts of the pebbles and between the pebbles and the matrix. Wide range in size of the pebbles

[14] Mathews, E. B., and Grasty, J. S., Idem, p. 378.

[15] Merrill, George P., and Mathews, Edward B., The Building and Decorative Stones of Maryland. Md. Geol. Survey, vol. 2, 1898, 187–193.

and in the relative amounts of pebbles and matrix leads to many difficulties in polishing the rock. The hard quartz pebbles tend to break away from the softer matrix, leaving cavities in the polished surfaces.

Difficulties in quarrying and polishing the rock due to the unusual physical characters have prevented the use of this stone to the extent that its uniqueness and beauty would invite. The first use of the stone was for the pillars in the Hall of the Representatives in the Capitol over 100 years ago. These pillars are 3 feet in diameter and 20 feet in height.

Frederick Limestone

The slabby beds of the Frederick limestone were extensively used in constructing houses in Frederick Valley and they are still used for foundations, walls, sills and stone fences.

Triassic Red Sandstone[16]

The harder beds of red sandstone from the Triassic formations were formerly used for building purposes. They were most extensively worked in Montgomery County in the vicinity of Seneca Creek and the stone was known in the trade as "Seneca Red" sandstone.

The color of the stone varies with the composition. The usual range in color is from light reddish brown or cinnamon to chocolate or deep purple brown. With an increase in quartz the lustre of the rock brightens and with an increase in feldspar the tone becomes gray. An unusually feldspathic rock near Taneytown is bright gray in color. An increase in the amount of cement deepens the color.

The stone was quite popular during the early and middle parts of the last century. The Smithsonian Institution and much of the stone-work of the Chesapeake and Ohio Canal were built with it. It may have lost its popularity largely because it showed a tendency to flake and spall in many of the buildings in which it was used. This was not the fault of the stone, but of the stone cutters and builders in setting the stone on "edge" instead of on "bed".

The only quarry in Frederick County that competed with the Montgomery County Seneca stone was located near Washington Junction. A spur track, $1\frac{1}{2}$ miles in length, connected the quarry with the railroad and a wharf on the Chesapeake and Ohio Canal. The operation was well equipped with saws, rubbing beds, and polishing machines. It furnished stone for such buildings as the Fort McHenry Hospital in Baltimore, churches at Forest Glen, Maryland, and Winchester, Virginia, and many houses in Washington.

Many small local quarries furnished foundation stone and dimension stone for stone houses. Small intermittently operated quarries were north of Emmittsburg, and in the vicinity of Taneytown, Thurmont and Union Mills.

[16] Merrill, George P., and Mathews, Edward B., The Building and Decorative Stones of Maryland. Md. Geol. Survey, vol. 2, 1898, 199–208.

Quartzite[17]

The Cambrian quartzite on the south slope of Sugarloaf Mountain and elsewhere in the Piedmont upland and on Catoctin Mountain has been quarried for local building stone (Plate 19A).

The McGill Belt quarry at the base of Sugarloaf Mountain was connected with the canal by a tramroad several miles long. Striplings were used for rails and tram cars were hauled by horses. The quarries were worked prior to 1830 to furnish stone for the canal. They later furnished stone in the construction of the Baltimore and Ohio Railroad. Quartzite produced from local quarries was also used in buildings at Mount St. Mary's at Emmitsburg.

In buildings the quartzite has a fresh gray color. It has a dense even texture so that there is little absorption and consequently little frost action. In durability and strength it cannot be surpassed. The siliceous character of the rock, however, renders it difficult and expensive to work.

Flagstone

The thin bedded micaceous quartzites of the Setters formation are admirably suited for the production of flagstone. The formation occurs only in the southeastern corner of Carroll County, extending northeastward from the South Branch of the Patapsco River at Marriottsville to the North Branch of the Patapsco River, a distance of $1\frac{1}{2}$ miles. Lawrence Triplett operates a quarry at each end of this narrow zone of Setters formation.

The rock in the Ivory Ridge quarry at Marriottsville is unusually thin bedded and somewhat friable. The quarry on the North Branch is directly across the river from the Patapsco flagstone quarry in Baltimore County operated by Charles D. Julio Company, Inc.

CLAY

The residual clays overlying the limestones of Carroll and Frederick counties are suitable for the manufacture of common brick. The residual clays overlying the limestones of the Frederick valley make an excellent hard, red brick. Residual clays derived from the weathering of the argillaceous rocks have also been utilized in the manufacture of brick.

The residual clays occur as a surface mantle on the uneven surface of the underlying rock so that they vary considerably in thickness. The thicknesses range from a few feet to more than 25 feet.

Brick plants have been operated at Brunswick, Buckeystown, Emmitsburg, Frederick, Mt. Airy, Thurmont, Walkersville, and Westminster. The only present operators are the Frederick Brick Works, Inc., at the southeast edge of Frederick and the Hudson Supply and Equipment Company at Buckeystown. Both of these plants use residual clays of the Frederick Valley limestones.

[17] Idem., pp. 211–212.

BUILDING SAND

Building sand has been obtained from the residues of weathered highly quartzose limestone near the base of the Grove limestone in Frederick Valley. The distribuntio of the quartzose limestone is shown on the geologic map of Frederick County. These beds of the Grove limestone contain an abundance of quartz sand grains. As the calcium carbonate matrix is dissolved on weathering, the sand accumulates in shallow deposits on top of the unweathered quartzose limestone. The largest sand pits are 1½ miles south of Frederick on both sides of U. S. Highway 15.

ROOFING GRANULES

The Catoctin metabasalt and the aporhyolite of the late pre-Cambrian volcanic series of the Blue Ridge-Catoctin Mountain area are suitable for the manufacture of roofing granules and as a filler in various products and in decorative walks. The colors of the granules are unfading. The metabasalt granules have the green color that is favored for roofing granules, and the aporhyolite granules are purple.

A quarry and crushing plant on the Western Maryland Railroad near Flint Station, 3½ miles northwest of Thurmont, were abandoned in 1935. Both green and purple granules have been produced at quarries near Monterey, Pennsylvania, just north of the Frederick County boundary.

SOAPSTONE AND TALC

Extending northeasterly across the southeastern corner of Carroll County, from a little over a half mile west of Henryton on the South Branch of the Patapsco River, to the North Branch of the Patapsco River, is a zone of serpentine ranging from 0.1 mile to 0.5 mile in width. Locally the serpentine has been altered to soapstone and talc. The stone is being worked by the Clinchfield Sand and Feldspar Company along Piney Run about 1 mile northwest of Marriottsville and by Herbert I. Oursler north of the Baltimore and Ohio Railroad west of Henryton.

Clinchfield Sand and Feldspar Corporation[18]

The serpentine has for the most part been altered to an amphibolitic rock containing minor amounts of soapstone and talc. Locally the rock has been more completely changed to massive soapstone and to schistose talc.

Near the southeastern contact of the serpentine is a crushed zone about 35 feet wide in which the rock has been pretty thoroughly altered to soft flaky soapstone and usually flanked on each side by several feet of chlorite schist, much of which can be ground with the soapstone. A quarry has been opened in this zone on both sides of Piney Run. The usable stone has a width of about 75 feet. The production at present comes entirely from the larger quarry on the northeast side of Piney Run, which has a width of about 150 feet and a face about 180 feet high.

The rock is ground in a mill, Plate 18B, on the downstream side of the quarry to produce a pulverized product sized to 90% under 270 mesh which is used as a filler.

[18] The description of these deposits is mainly from a private report to the company by Dr. Frank L. Hess made available through their courtesy.

A special sized product, 3 to 4 microns in size, is now being used as a carrier for DDT. The harder stone is utilized for roofing granules.

About 200 yards northwest of the preceding quarries, near the northwest contact of the serpentine mass, is a zone about 600 feet wide of dense, massive soapstone that was formerly worked with channeling machines for the sawing of soapstone slabs for the production of wash tubs and bath tubs. The larger old excavation is about 200 feet long parallel to the road and about 50 feet wide. It is now filled with water but is reported to be 80 feet deep. A smaller channeled opening is about 100 feet to the northwest. Northwest of the latter excavation is a small old quarry in a narrow crushed zone which has been converted to schistose talc. Massive soapstone southeast of the large channeled excavation is being worked in a small quarry about 50 feet square with two faces at right angles to each other.

Herbert I. Oursler

On the Baltimore and Ohio Railroad, about one half mile west of Henryton, is a hammer mill and loading bin from which Herbert I. Oursler ships lump and crushed soapstone. From the top of the chute a small tramway ascends the northwest side of a ravine to a number of small openings extending some hundreds of feet along the hillside in which narrow layers of talc schist have been worked. The individual layers are usually only a few feet wide, but in some of the excavations were several such layers of talc separated by greater widths of less talcose, unusable chloritic schist.

FLINT (QUARTZ)

Flint is the trade name for massive crystalline quartz, usually milky white in color. It occurs in lenticular veins which trend parallel to the layers of the country rock. The veins are a quartzose facies of pegmatite and occur in the same general region in which the pegmatites are found. They occur abundantly throughout the crystalline schists of eastern Carroll County, and have been most extensively worked in the southeastern part of the county. A considerable part of the production has been from residual quartz masses and boulders found at the surface.

Localities at which flint has been produced are[19] the Brauning quarries, $1\frac{3}{4}$ miles north of Haight, which was one of the largest producers; the Bennett quarry, $\frac{3}{4}$ mile north of Haight; the Ruch quarry, $1\frac{1}{4}$ miles east of Eldersburg; the Flint Quarry Woods, which yielded a large tonnage from loose masses and boulders at or near the surface; the Oursler quarries, 1 mile north of Marriottsville; the Richardson quarry, $\frac{1}{2}$ mile west of Henryton; the Wesley Baker quarry, 1 mile east of Gorsuch; the Emma Feazer quarry, $1\frac{1}{2}$ miles east of Sykesville; the Ruby quarry, $\frac{3}{4}$ mile north of Gaither; and the Trayer farm, 1 mile northwest of Hoods Mills.

There were formerly flint grinding mills at Hoods Mills on the Baltimore and Ohio Railroad and at Finksburg on the Western Maryland Railroad. The Maryland Silicate Company's mill at Finksburg was shut down in 1910 and the Patapsco Flint Mill Company's mill at Hoods Mills some years earlier. After these mills shut

[19] Singewald, Joseph T., Jr., Feldspar, Quartz, Chrome and Manganese in Maryland. Md. Geol. Survey, vol. 12, 1928, 146–149.

down, flint quarrying continued and the output was shipped to Golding Sons Company at Trenton and to the U. S. Sandpaper Company. The quarries were worked actively during the World War.

The only present operator is the Clinchfield Sand and Feldspar Corporation. Its quarries are on a large lenticular quartz vein in the Flint Quarry woods, or Frank Thomas woods, overlooking the North Branch of the Patapsco River, 2 miles north of Marriottsville. This is the largest deposit of quartz that has been found in the area. The outcrop extends more or less continuously with a northeasterly strike along the northwest slope of a ridge for several hundred feet. Below the outcrop are numerous huge masses of float quartz. The quartz is crushed and ground at the Company's soapstone mill, 1 mile northwest of Marriottsville. The mill produces five sizes according to specifications. A special ceramic grade for white grinding wheels contains less than 0.008% iron.

The principal uses of flint are in the manufacture of pottery, as an abrasive, and as a filler. It is also used in the metallurgical industry for the manufacture of silicon alloys and in lump form as a filler for acid towers. The pottery industry requires a low iron content. It is used in pottery to lessen shrinkage. Its abrasive qualities are due to its hardness, brittleness, and lack of cleavage, resulting in sharp angular fragments on crushing. Finely ground flint is used in the manufacture of wood filler and paints. Gravel and granule sizes are also used for roofing, stucco, and poultry grit.

FELDSPAR

Feldspar has been produced only in the vicinity of Marriottsville and Henryton in the southeastern corner of Carroll County.

Feldspar is obtained from the rock known as pegmatite which occurs in more or less lens-shaped masses which have been intruded parallel to or nearly parallel to the foliation of the intruded rock. The pegmatite may occur as a single mass along a definite plane of foliation or as a group of bands and lenses along a number of planes of foliation. The individual bodies of pegmatite range in size from a few inches to tens of feet in width, and from tens of feet to a mile or more in length.

Most of the feldspar produced in Carroll County has come from the southwestern ends of the two pegmatite intrusions shown on the Carroll County map extending northeastward from the South Branch of the Patapsco River between Henryton and Marriottsville to the North Branch. The quarries that have produced feldspar are[20] the Weetenkamp quarry at Marriottsville; the Tunnel Mine at Marriottsville, the only place in Maryland where feldspar has been mined; the DeVries quarries to the northeast of Henryton; the Wallen quarry, ½ mile northwest of Marriottsville; and the Oursler quarry, 1 mile north of Marriottsville.

One of the largest pegmatite dikes in the State extends across the DeVries farm. It comes in from the Howard County side of the South Branch of the Patapsco River, passes through the Baltimore and Ohio Railroad tunnel at Henryton, and is exposed for a half mile along the steep hill side on the north side of the river. It has a width

[20] Singewald, Joseph T., Jr., Feldspar, Quartz, Chrome and Manganese in Maryland. Md. Geol. Survey, vol. 12, 1928, 118–119.

of 50 to 100 feet. The dike as a whole carries too much mica to be quarried successfully for pottery-grade feldspar although limited quantities were sorted out without excessive cobbing at several places along the dike. The pegmatite was worked about 10 years ago by The Standard Lime and Stone Company for use in the manufacture of rock wool.

The feldspar in pegmatite is intergrown with quartz, mica and a number of accessory minerals. Pottery grade feldspar must be low in iron, so that the rock has to be carefully cobbed to reduce the amount of associated iron-containing minerals. A large amount of quartz is also objectionable, and quartz is eliminated by cobbing. Usually at least half of the rock quarried is rejected as waste. Most of the Carroll County production was sold to the grinding mills at Trenton. There has been little production of feldspar in Carroll County, or even in Maryland, during the last 25 years. No feldspar is being produced in Carroll County at present.

BARITE

Barite has been found at a number of places in Carroll and Frederick Counties in residual soil on the Wakefield marble and as filling in fractures in crushed and fissured marble. It also occurs sparingly as a gangue mineral in the copper ores of these counties. The only locality at which it has been found in abundance is at the Sauble limestone quarry in Frederick County.

Sauble Barite Prospect[21]

The Sauble limestone quarry is located on a small tributary of Beaver Dam Creek, 1½ miles southeast of Johnsville. The barite occurs in small bands and stringers in fractured marble. In working the quarry for limestone, the barite was sorted out and thrown aside.

IRON ORE

HISTORY OF IRON INDUSTRY

During the Colonial period and during much of the last century the iron industry was an important and widespread industry in Maryland. Nearly all of these small operations had been abandoned by the end of the century. Carroll and Frederick Counties participated in this iron industry.[22]

Carroll County

Legh Furnace.—The Legh Furnace was built at Avondale, about 1765, by an Englishman named Legh Master, but operated for only one or two blasts. A portion of the old stack still marks the site.

Elba Furnace.—The Elba furnace was erected at Warfield station on the Baltimore and Ohio Railroad, on the north bank of the Patapsco River in 1847 by James W. Tyson. Part of the brick-lined granite stack is still standing. It was a steam and water charcoal furnace. The ore was obtained chiefly from the Springfield mine,

[21] Watson, Thomas L., and Grasty, J. Sharshall, Barite of the Appalachian States. Trans. Am. Inst. Min. Eng., vol. 51, 1916, pp. 530–532.

[22] Singewald, Joseph T., Jr., Iron Ores of Maryland. Md. Geol. Surv., vol. 9, pt. 3, 1911, pp. 146–150.

north of Sykesville, from near Mt. Airy, and carbonate ore from near Relay. The property was destroyed by a flood in 1868.

Frederick County

Catoctin Furnaces.—These furnaces were situated on the Frederick and Emmittsburg road, 3½ miles south of Thurmont. In 1770, Leonard Calvert and Thomas Johnson were granted a patent for this tract of 7,000 acres, which in 1774 passed into the hands of the brothers, Thomas, Baker, Roger, and James Johnson, by whom the first furnace was erected in that year. It was operated successfully until 1787, when a new furnace was erected about ¾ mile further up Little Hunting Creek, and nearer the ore banks. In 1793, the property was divided. The furnace was taken over by Thomas and Baker Johnson who operated without much success until 1803. Baker Johnson then bought out his brother and leased the property for 10 years to Benjamin Blackford. At the expiration of the lease, it was sold to Willoughby and Thomas Mayberry. In 1820, the property was sold by trustees to John Brien and was operated by him and his heirs until sometime after 1840, when it came into the possession of Peregrine Fitzhugh. The erection of a steam cold-blast charcoal furnace in 1859 crippled him financially and the property was acquired by John Kunkle and operated by his sons, John B. Kunkle and Jacob M. Kunkle. An anthracite and coke furnace, with a capacity of 35 tons a day, was erected in 1873. Upon the death of John B. Kunkle in 1885, his children formed the Catoctin Iron Company which went into the hands of receivers in 1887. The receiver operated the property in 1888, and then the Catoctin Mountain Iron Company was formed which lasted until 1892. A paint mill was erected and operated during this period, producing blue, red and yellow ochre. In 1899 the property was sold to the Blue Mountain Iron and Steel Company which operated from May, 1900, to February, 1903. In 1905 the property was sold in court to Joseph E. Thropp, of Earlston, Pennsylvania, who dismantled the furnaces and worked only the ore banks for his furnaces in Pennsylvania.

Connected with the operation of the first furnace was a forge about 2 miles above the mouth of Bush Creek and a slitting and rolling mill at Reel's Mill. The forge was operated until 1810.

Hampton Furnace.—Old Hampton Furnace was built between 1760 and 1765 on Toms Creek, 1½ miles west of Emmittsburg. Ore from the Catoctin ore banks was used before the Catoctin furnace was built. The furnace was soon abandoned for want of good ore.

Fielderia Furnace.—This furnace was built in 1789 to 1790 on the Harpers Ferry road, 3 miles from Frederick. It made but one blast and was then abandoned. John Hoffman of Frederick built a grist mill on the site.

Johnson Furnace.—The Johnson furnace was erected in 1787 by the owners of the Catoctin furnace on the south side of Furnace Branch, a tributary of the Monocacy River, about 1½ miles northwest of Dickerson. It was operated by Roger Johnson until sometime after 1800. The ore was mined at Point of Rocks. A forge run in conjunction with this furnace, the Bloomsburg forge, was located on Big Bennetts Creek, about 5 miles above its confluence with Monocacy River. The forge was abandoned between 1800 and 1805.

Lonaconing Furnace.—The Lonaconing furnace at Knoxville was built in 1848 by Barker and Company of Baltimore, but operated only a short while. It was rebuilt in 1868 by Christian Geiger. After running it a year, he sold it to a Pittsburg Company which operated it about 10 years longer.

THE IRON ORES

The three principal kinds of iron ore, limonite, hematite and magnetite, occur in Carroll and Frederick Counties, but the limonite deposits are the most numerous and yielded most of the production. Many of the iron ore mines are described in the report on the Iron Orés of Maryland.[23]

Limonite Ores in Carroll and Frederick Counties

Limonite deposits occur in the Cambrian shales of Frederick County, at fault contacts of the Frederick Valley limestones, and in the crystalline limestones of the Piedmont in Carroll and Frederick Counties.

Limonite in Cambrian Shales.—Deposits of this type occur in Frederick County along the foot of Catoctin Mountain and in a small valley east of Frederick Valley south of Frederick Junction.

The most extensively worked deposit occurs along a fault between the Antietam quartzite and the Tomstown dolomite. It was worked in a series of openings extending northward from Point of Rocks for over 3,000 feet along a small stream. The limonite occurs in lumps in a blue clay and in weathered shale. An analysis of a sample of the ore exposed in the old openings shows 38.50% iron and 21.23% silica. In the early part of the 18th century the ore was used at the Johnson furnace near Dickerson. The deposit was again actively worked in the 70's and the ore shipped to Pittsburg. About the same time two smaller deposits, the Nina Thomas Ore Bank, and the Zimmerman Ore Bank, about 1½ miles southwest of Feagaville, were also worked. The Thomas ore was used at the Lonaconing furnace at Knoxville and shipped to Pittsburg from Frederick.

Similar deposits of limonite nodules in weathered shale were worked before and after the Civil War at the Kiefer Thomas Ore Bank and the Dave Thomas Ore Bank, ¾ mile and 3½ miles respectively south of Frederick Junction in the small valley east of the Monocacy River, and at the Grim Ore Bank, 1 mile southeast of New Midway.

Limonite in Cambro-Ordovician Limestones.—These deposits occur as nodules of limonite embedded in clays along fault contacts of the limestones and in residual clays overlying the limestones.

The largest deposits of the fault contact type were those on the Catoctin property, on the west side of Frederick Valley, along the foot of Catoctin Mountain, 3 miles south of Thurmont. The several openings extended 1½ miles along the foot of the mountain. The largest deposit was worked for a distance of over 2,000 feet along the strike and over a width of 800 feet. The ore was a good grade of non-Bessemer limonite occurring in lumps of various sizes in blue and yellow clay. Seven tons of clay yielded one ton of lump ore. Five samples of the ore showed the following range in composition:

[23] Loc. cit., pp. 193–202; 203–206; 206–218; 308–311; 312–318.

	Minimum	*Maximum*	*Average*
Fe	37.21	42.82	40.28
SiO_2	16.16	25.32	20.57
Al_2O_3	5.38	7.45	6.41
Mn	0.15	3.41	1.39
CaO	0.60	1.01	0.72
MgO	0.27	0.80	0.48
P	0.18	0.43	0.29
S	0.05	0.09	0.06
Ignition loss	9.55	11.62	10.84

The deposits lie along the fault and extend over into shale on the west and overlie limestone on the east. Mining on this property began in 1774 and the ore was smelted in furnaces erected on the property until 1905 when it was acquired by Joseph E. Thropp of Earlston, Pennsylvania, who shipped the ores to his furnaces in Pennsylvania for about ten years.

Limonite in Piedmont Limestones.—These deposits consist of nodules of limonite embedded in clay along the contact of the limestone and the schistose rocks of the Piedmont.

Most of the productive deposits were in the narrow limestone valleys in northeastern Carroll County, extending from Lineboro at the State Line to Westminster and for several miles further southwest, especially in Bachman Valley which was served by a branch line of the Western Maryland Railroad from Pennsylvania that extended to Ebbvale. Active operators were the Chestnut Hill Mining Company, the Mason and Dixon Mining Company, and the Ebbvale Mining Company. Most of the ore was shipped to Pennsylvania furnaces. The ores were an excellent grade of non-Bessemer limonite. Analyses of six samples showed the following range in composition:

	Minimum	*Maximum*	*Average*
Fe	45.43	52.39	48.53
SiO_2	4.48	9.10	6.37
Al_2O_3	2.85	7.10	4.16
CaO	0.49	1.12	0.69
MgO	0.13	0.54	0.30
Mn	0.85	3.79	2.06
P	0.57	1.43	1.19
S	0.04	0.08	0.05
Ignition loss	12.66	14.66	13.88

The mining of these ores dates back to the Colonial Period and continued into the second decade of this century. Deposits that were worked were the Keeny, 1½ miles east of Lineboro; the Meyer, 1 mile west of Lineboro; the Miller, 1½ miles southwest of Lineboro; the Peterman banks, 1 mile northeast of Melrose; the Chestnut Hill banks, in the vicinity of Ebbvale; the Nellar, 2 miles south of Ebbvale; the Schaeffer, ¾ mile southeast of Bachman Mill; the Wareheim, 1 mile southwest of Bachman Mill; the Maus, ½ mile west of Bixler; the Hunter, 1 mile north of Westminster; the Copps Branch, 1 mile west of Westminster; and the Avondale banks at Avondale.

A similar deposit in Frederick County was worked at the Ensor Ore Banks, 1 mile northeast of Unionville.

Specular Hematite in Carroll County

A lenticular quartz vein containing specular hematite, magnetite, and copper ore minerals extends from Sykesville to Finksburg, closely paralleling the metagabbro dike shown on the geologic map of Carroll County. The strike of the vein is parallel to the strike of the country rock schists and the dip is usually nearly vertical. The wall rock varies from mica schist to talcose and chlorite schist. The width of the vein is extremely variable and ranges from almost nothing to over 15 feet. In the southern portion the iron ore mineral is mainly specular hematite. Toward the north magnetite is abundant, and at Finksburg the iron ore mineral is almost entirely magnetite. The vein produced both iron ore and copper ore. At the south end, at the Springfield mine, copper minerals did not appear abundantly enough to constitute copper ore until a depth of 60 feet had been reached. To the north copper ores become abundant nearer the surface, and at Finksburg, they extend to the surface.

Mines and prospects along this vein were the Springfield mine, 1½ miles north of Sykesville; the Carroll mine, 2 miles north of Sykesville; the Monroe prospect, 1 mile north of Eldersburg; the Beasman prospect, 1½ miles southeast of Louisville; the Mineral Hill mine, 1 mile southeast of Louisville; and the Patapsco mines, at the eastern edge of Finksburg. The mines are more fully described in the section on copper ores.

The iron ore in the upper part of the vein in the Springfield mine has the composition:

Fe	46.77
SiO_2	30.66
Al_2O_3	1.89
Mn	0.18
P	0.11
S	0.05
Ignition loss	0.43

After lying idle for many years, the Springfield mine was worked during the World War to furnish ore for the manufacture of ferro-silicon in Baltimore by the Shawinigan Electro Products Company. The Mineral Hill mine is said to have been worked as early as the Revolutionary War. At times a hundred men are said to have been employed at this mine. The ore was crushed, washed and picked. Some of the ore was sent to the Elba furnace at Sykesville, and the rest hauled to Finksburg for shipment. The Patapsco mines were opened about 1850, and some of the ore was shipped to Baltimore.

Magnetite Ores in Frederick and Carroll Counties

Magnetite ores have been produced from the Loudon formation on Catoctin Mountain and from the Piedmont schists in southeastern Frederick County and southwestern Carroll County.

Magnetite Ore in the Loudoun Formation.—A magnetite bed in the Loudoun formation is exposed at the top of the hill three miles southwest of Catoctin and three miles north of Thurmont. Whether this is a sedimentary deposit that may be continuous between these two exposures or whether these are isolated occurrences is not known.

The ore has been worked only at the locality southwest of Catoctin where a number of pits were sunk and one larger opening made along the ridge. A small quantity of ore was used at the Catoctin furnaces. The country rock is a dark blue shale with disseminated fine-grained magnetite and some pyrite. The ore bed has a thickness of less than 6 feet and consists chiefly of grains of quartz and magnetite. An analysis of a sample of the ore is:

Fe	35.02
SiO_2	33.82
Al_2O_3	9.43
CaO	1.04
MgO	1.50
Mn	0.16
P	0.04
S	0.27
Ignition loss	1.98

A report on an investigation of the ore in 1896 states that careful separation yielded a concentrate having the composition:

Fe	65.2
SiO_2	6.25
P	0.028
S	0.038

Magnetite Ore in Piedmont Schists.—The Piedmont schists frequently contain disseminated magnetite, and at a few places the magnetite is sufficiently abundant to give rise to an ore body of small size. Several small limonite deposits in the schists are probably derived directly from the weathering of such magnetite deposits or are local concentrations from more sparsely disseminated magnetite and other iron minerals in these rocks.

Ore banks at which deposits of this type were worked are the Patrick Ambush, 1½ miles southwest of Park Mills; the Yingling, ½ mile northeast of Greenfield Mills; and the Clary, 2 miles northwest of Mount Airy, in Frederick County; and the Richmond mine, ½ mile east of West Falls; and the Hood mine, 4½ miles northeast of Mt. Airy, in Carroll County.

On the McGill Belt farm, 2 miles north of Dickerson, are surface indications of magnetite ore in bluish green and pink schistose volcanic rock. A sample of the float ore has the composition:

Fe	58.67
SiO_2	8.26
Al_2O_3	3.18
Mn	trace
P	0.00
Ignition loss	3.64

COPPER ORE

Copper ores are found in three areas in Carroll and Frederick Counties, on the eastern slope of South Mountain in northwestern Frederick County, between Union Bridge, New Windsor and New London in eastern Frederick County and the adjacent part of Carroll County, and between Finksburg and Sykesville in southeastern Carroll County.

SOUTH MOUNTAIN COPPER ORES

Native copper and the oxide of copper, cuprite, occur in the Catoctin metabasalt in association with quartz, epidote and asbestiform serpentine in local segregations in joint fractures. Their oxidation products malachite and azurite stain the metabasalt green and blue. The ore has been prospected at several places north of Sensenbaugh School, east of the Smithsburg-Wolfsville road. Further north along South Mountain, in Pennsylvania, ores of this type have been more extensively prospected and unsuccessful attempts have been made to mine them.

COPPER ORES IN THE WAKEFIELD MARBLE

The copper deposits in the Wakefield marble in eastern Frederick County were at one time of considerable economic importance. They were last worked during the World War. The most productive mines were the New London mine, just west of New London; the Dolly Hyde mine, $\frac{1}{4}$ mile east of Libertytown; and the Liberty mine, 2 miles north of Libertytown. Less productive were the Repp mine, 1 mile southeast of Johnsville; the Cox mine, 2 miles northeast of Johnsville; and the Roop mine in Carroll County, $1\frac{1}{2}$ miles south of New Windsor.

The copper ores occur in shear zones in the Wakefield marble near its contact with the overlying volcanic rocks as fillings of fissures and breccias and as replacements of the marble. The ore minerals are chalcocite, bornite, and chalcopyrite. The gangue minerals are calcite, quartz, and barite.

These deposits and the mines have been described repeatedly in publications since 1840, but the most comprehensive geologic description is that by Overbeck in 1916.[24]

New London Mine

The New London mine was opened about 1835 by Isaac Tyson, Jr. and actively worked until sold in 1855. It appears to have been worked only intermittently during the period from 1855 to 1907 when it was acquired by the Linganore Copper Company of Frederick. A concentrating plant was then erected and the mine was worked actively until 1917. In 1913 the Linganore Copper Company was merged with the United Milling and Smelting Copper Company which controlled also the Dolly Hyde mine.

In 1839, the shaft had reached a depth of 114 feet and in 1914 it had a depth of 300 feet. It is said to have reached a depth of 435 feet when the mine was closed down in 1917. The stope length of the ore body does not appear to have been as

[24] Overbeck, R. M., A metallographic study of the copper ores of Maryland. Economic Geology, vol. 11, 1916, pp. 151–178, 504–506.

much as 300 feet on any level. On the east the ore body terminated at a fault. The concentrating plant erected by the Linganore Copper Company had a capacity of 100 tons. The crude ore is said to have averaged 3.65 per cent copper and the concentrates about 24 per cent copper and about 2 cents silver.

The ore body is in a fissure which cuts across an impure limestone composed of alternating bands of limestone and soft gray phyllite. Two types of ore occur: massive ore in relatively pure limestone consisting of masses of chalcocite, calcite and quartz; and schistose ore in rock consisting largely of phyllite with narrow bands of limestone replaced by chalcocite. Associated with the chalcocite is a little bornite.

Dolly Hyde Mine

The Dolly Hyde mine was opened in 1839 and was acquired about 1845 by Isaac Tyson, Jr., who operated it until 1855 when he sold it to the Dolly Hyde Copper Company. This company was soon after drowned out and no further attempt to operate the mine was made until 1914, when the United Milling and Smelting Copper Company made an attempt to reopen the mine but abandoned operations again before achieving production.

Descriptions of the ore deposit and of the ore are available only in the literature dating back from 1860. The deposit occurs in a narrow limestone valley bounded on each side by volcanic schists. The workings did not attain to depths of more than a few tens of feet and apparently did not extend below the supergene ores. Ducatel in 1839 described the ore as soft and friable oxides of iron and manganese, copper black and copper carbonate with occasional large masses of copper carbonate. Whitney in 1854 said galena containing 45 to 50 oz. silver increased in quantity in depth. Jackson in 1853 said the limestone had a strike of N 75° E and dip of 45° SE and that a branch of the limestone went off to the northwest. The richest mineralization occurred at the split in the limestone where bornite occurred in the marble over a width of 2 to 3 feet. The few specimens remaining at the surface found by Overbeck consisted of limestone with thin stringers of chalcopyrite and bornite and disseminated grains of galena.

Liberty Mine

The Liberty mine was opened before 1760 and was shut down during the Revolution and for some years thereafter. It was reopened in 1838 by Isaac Tyson, Jr. who built a small furnace but shut down again in 1839. In 1865 Tyson transferred the property to the Liberty Mining Company. The mine was foreclosed on account of a mortgage in 1876 and operated by the new owners until 1885. Production was resumed in 1906 by the Virginia Consolidated Copper Company, and continued intermittently with changes in ownership until 1918. Concentrates produced during this latter period are said to have averaged 24 per cent copper and 1.3 cents silver. On the other hand, the ore in 1907 is reported to have averaged 2.16 per cent copper 4.7 oz. silver and $1.80 gold.

Much of the mining was done in open cuts. The largest open cuts are within an area about 300 feet long from north to south and 200 feet wide from east to west. Numerous small prospect pits extend for a distance of about 600 feet to the south.

Little prospecting was done to the north. Underground mining was carried on principally from two points known as the Old Workings and the New Workings. Most of the underground workings do not appear to have exceeded 100 feet in depth, though a shaft at the Old Workings is reported to have reached a depth of nearly 400 feet.

The country rock is a fine-grained dolomitic limestone traversed by stringers of coarse-grained calcite. In part it is pure limestone and in part mixed limestone and schist. The ore minerals are principally chalcocite and bornite. Chalcopyrite is rare. Malachite is widespread but small in quantity. The gangue minerals are calcite, quartz, and barite. The ore occurs in stringers and bunches irregularly distributed through the limestone where it had been fractured.

Repp Mine

This mine is said to have been opened before the Revolutionary War, but apparently was never extensively worked and has been idle for many years. Old workings consisting of three shafts and a tunnel were partly cleaned out in 1941 by L. A. Baumgardner of Frederick and Edwin R. Gill of New York, and samples of the ore assayed. Mr. Baumgardner said the assays ranged from 0.12 per cent to 5.79 per cent copper, from 0.23 oz. to 1.44 oz. silver, and 0.01 oz. to 0.06 oz. gold. The average of the six samples is 3.21 per cent copper, 0.83 oz. silver and 0.3 oz. gold.

The country rock is white and pink to purple crystalline, dolomitic limestone. The ore traverses the limestone in narrow stringers. Chalcopyrite appears to have been more abundant here than at the other mines.

Cox Mine

This mine was worked for only a short while about 100 years ago. The workings consist of three open cuts and a tunnel on the east side of Beaverdam Creek, about ¼ mile north of the Six Lead Mine. The workings are in mottled white, pink and purple crystalline limestone close to its contact with purple and green schists. Bornite, chalcopyrite, galena, malachite, and copper oxides are found on the dump. Mr. L. A. Baumgardner has specimens of almost pure chalcocite, bornite, chalcopyrite, and malachite which he said he obtained from the dump. He said assays of specimens ran as high as 33 oz. silver.

Roop Mine

The Roop mine was worked for a short time in 1879 and 1880 when it was described by Frazer. The discovery of copper ore in quarrying limestone on the Roop farm led to prospecting and a little mining on this farm. The workings extended over an area nearly 2,400 feet long from northeast to southwest and over a width of about 1,200 feet. They were no more than shallow prospect pits and trenches, except for two shafts, 45 to 50 feet deep, south of the Roop house. The mineralized rock ranged in width up to 5 and 6 feet, but the mineralization apparently did not extend beyond the pockets exposed by the workings. The ore occurred in limestone close to its contact with chloritic schists. The ore minerals are chalcocite, bornite, and chalcopyrite, and their oxidation products, such as malachite. In the southeasterly prospect openings sphalerite is abundant and galena also occurs. Frazer gives three analyses of samples prepared by him which show 23.70 per cent and 12.90 per cent copper and 40.93 per cent zinc sulphide, respectively.

Pittinger Prospect

The Pittinger prospect is on the west side of Toms Branch, $\frac{3}{4}$ mile south of Libertytown. Only two small prospect pits were dug here. The limestone contains small stringers of chalcocite and bornite stained with malachite. Larger pieces of bornite are found on the dump. Five samples taken from outcrops by L. A. Baumgardner are said to have ranged from 0.85 per cent to 8.65 per cent copper, from 0.10 oz. to 0.61 oz. silver, and from a trace to 0.01 oz. gold. The average of the five samples is 2.63 per cent copper, 0.22 oz. silver, and 0.004 oz. gold.

COPPER ORES IN SOUTHEASTERN CARROLL COUNTY

The copper ores of southeastern Carroll County closely follow a dike of hornblende gabbro that extends across the county from the North Branch of the Patapsco River east of Finksburg to the South Branch of the Patapsco River west of Sykesville. The vein is a lenticular vein approximately parallel to the country rock and lies either in the hornblende gabbro or a short distance west of the hornblende gabbro in the Peters Creek formation. The mines located along this vein are the Patapsco Mine, at the eastern edge of Finksburg; the Mineral Hill Mine, about $\frac{4}{5}$ mile southwest of Louisville; the Carroll Mine, $1\frac{1}{2}$ miles north of Sykesville; and the Springfield Mine, 1 mile north of Springfield. These mines have produced both iron ore and copper ore.

The ore minerals are chalcopyrite, bornite, chalcocite, covellite, carrollite, sphalerite, specularite and magnetite. The gangue minerals are chiefly the minerals of the country rock, hornblende, biotite, epidote and feldspar. Copper minerals are encountered at the surface at the north end of the mineralized zone and at increasing depths and in decreasing quantity toward the south. Specularite predominates at the south end and magnetite at the north end.

Patapsco Mine

The Patapsco mine is at the eastern end of Finksburg. The principal shaft was on the north side of the State Highway and reached a depth of 350 feet with levels extending 600 feet along the vein. A shaft on the south side of the highway had a depth of 100 feet. The mine was opened in 1849 by E. Remington and the Patapsco Mining Company. Later the Patapsco Copper and Cobalt Mining Company was formed. Furnaces built to smelt the ore were never used, and operations ceased in 1865. The mine was reopened in 1880 and worked for a few years for magnetite ore.

The rock on the dumps consists of several types of hornblende schist, one of which is made up of hornblende with small amounts of magnetite and biotite, and another of hornblende, zoisite, plagioclase feldspar, quartz, and epidote. There is also a small amount of pegmatite. Tyson described the deposit as a "true vein" that "became thinner, or pinched off" in depth. The ore contained chalcocite, bornite, chalcopyrite and carrollite together with their oxidation products, and much magnetite, and occurred in both the schist and the pegmatite. The rare cobalt mineral carrollite was first described from this mine.

Mineral Hill Mine

The Mineral Hill mine was opened in pre-Revolutionary times. The ore was treated in a furnace 1½ miles northeast of the mine and the copper brought to Baltimore. The mine was covered up at the time of the Revolutionary War and its existence apparently forgotten. In 1849, the mine was reopened by Isaac Tyson, Jr. and worked by him until 1861 when a new company was organized. Work was carried on intermittently by this company until 1890. In 1854, three shafts had depths of 250, 160, and 90 feet respectively, and levels were run at 100 and 160 feet. Later an adit was driven into the hill 450 feet to meet a shaft with an inclination of 50° that followed the vein for a distance of 370 feet.

The immediate country rock of the vein appears to be biotite, amphibole, chlorite, and talc schists containing epidote, zoisite, quartz, and magnetite. The vein conforms to the strike and dip of the schists and has a width of 2 to 6 feet. Copper ore occurred on the hanging wall side of the vein and iron ore on the foot wall side. The values were unevenly distributed in the vein. The mineralogy of the ore is the same as at the Patapsco mine.

Carroll Mine

The Carroll mine was worked from two shafts and an adit. In 1854 the shafts were 72 and 150 feet deep and the adit had a length of 210 feet. It was probably started in the 1840's and was being worked in the 1850's. It is not known when it was last worked, but it has been abandoned for many years. A banded quartz-specularite rock is exposed at the old openings. The mine was never an important producer of copper ore.

Springfield Mine

The Springfield mine is situated about ¼ mile south of Piney Run. It was opened in 1849 by Isaac Tyson, Jr. as an iron mine. At a depth of about 60 feet, chalcopyrite became abundant and the mine was worked as a copper mine. The Springfield Mining Company was organized in 1855 and continued operations until 1869 when the pillars were robbed and the mine caved in. It was not worked again until 1916 when it was worked as an open cut to produce quartz-specularite ore for the manufacture of ferro-silicon in Baltimore by the Shawinigan Electroproducts Company.

In 1853 the shaft had reached a depth of 210 feet and the mine was producing from 500 to 1,200 tons of ore annually. In 1860 the shaft was 700 feet deep and Philip Tyson said the ore yielded 13 per cent copper. The copper production at that time was:

	tons
1858	475
1859	684
1860	738
1861	1728

At the outcrop the ore body is a quartz specularite schist consisting of a light gray quartzite with thin bands of specularite and magnetite. The copper ore encountered in depth consisted of quartz, magnetite and chalcopyrite.

PRODUCTION OF COPPER ORES

No systematic records are available of the production of copper ores in Carroll and Frederick Counties during the years when the mines were most actively worked, so that no estimate can be made of the amount of copper these mines have produced.

During the present century only the Liberty mine and the New London mine have been worked, and most of the production came from the New London mine. The production as reported in the annual volumes of the Mineral Resources of the United States was:

1907	small quantity of concentrates
1908	a few hundred pounds
1911	23,555 pounds metallic copper
1912	53,043 pounds metallic copper
1914	12,248 pounds metallic copper
1915	15,426 pounds metallic copper
1916	126,965 pounds metallic copper
1917	291,501 pounds metallic copper

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LEAD AND ZINC ORE

Galena and sphalerite, the common ore minerals of lead and zinc respectively, are associated with the copper ores of Carroll and Frederick Counties and in places occur in appreciable quantities. The only mine in which lead and zinc greatly exceeded copper in amount is reported to have been the Mountain View mine.

Though Williams calls a mine opened shortly before 1891 the Mountain View lead mine, he describes it as on the Cox farm. He says in 1891 three small shafts had been sunk in the deepest of which galena had been oxidized to anglesite, cerussite, and sulphur.[25] He mentions also the occurrence of a small amount of chalcopyrite altering to bornite and malachite. This would appear to be the same locality as the Cox Mine described as a copper mine.

Mountain View Lead Mine

The Mountain View lead mine was also called the Six lead mine and known also as the Shivers mine. It is situated 2 miles southwest of Union Bridge and 1¾ miles northeast of Johnsville. It lies nearly ½ mile north of the road from Johnsville to New Windsor and nearly ½ mile northwest of the Six farm house at the boundary between the Six farm and the Margaret Englar farm. The mine is reported to have been worked a short while about 1880, when the lead ore was sorted out and shipped and the zinc ore thrown on the dump. It is said to have been worked again for a short while in 1910. It was unwatered and the workings inspected in 1941 and again in 1942 by Edwin R. Gill and W. W. Howe of New York and L. A. Baumgardner of Frederick.

The workings consist of an incline 15 feet deep which opens into a flat stope 65 feet long, 35 feet wide, and 15 feet high, and two shallow cuts 20 and 40 feet to the southwest. Lead prospect openings are said to extend as far southwest as the narrow zone of limestone crossed by the Copper Mine road, 1½ miles south of Johnsville.

Five samples of selected specimens and four samples of supposedly run of mine ore taken by Mr. Baumgardner showed the following range in composition:

[25] Williams, G. H., Anglesite, Cerussite and Sulphur from the Mountain View Lead Mine near Union Bridge, Carroll County, Maryland. Johns Hopkins University Circular, vol. 10, No. 87, 1891, pp. 73-75.

	Copper %	Lead %	Zinc %	Gold oz.	Silver oz.
Selected specimens....	4.06–39.2	4.6 –62.4	10.9 –17.5	0.01–0.02	1.40–33.14
Ore samples..........	0.95– 1.20	1.60– 4.75	1.42– 6.30	0.02–0.10	tr. – 1.16

The ore minerals are galena, dark gray sphalerite, and chalcopyrite and a little bornite. The gangue is mainly coarse-grained calcite and fine-grained limestone country rock. Quartz occurs sparingly. The ore minerals occur along tight shatter cracks in the limestone and replacing the limestone.

The ore is in a narrow belt of Wakefield marble, bounded on the east by the Ijamsville phyllite and on the west by metarhyolite. The marble dips 20° to 30° to the southeast. The ores occur in the marble close to the phyllite contact.

GOLD ORE

Gold occurs in small quantity in quartz veins carrying pyrite in rocks of the Piedmont upland, but no production of gold has been reported. A shallow shaft has been sunk in a search for workable gold ore northeast of Woodbine in Carroll County.

WATER RESOURCES OF CARROLL AND FREDERICK COUNTIES

SURFACE-WATER RESOURCES

BY

A. H. HORTON

The surface and ground water resources of any area or region depend primarily on precipitation, its seasonal distribution and the climatic conditions; and to a lesser extent on topography, character of the soil and its cover, and the geologic formation of the area. The topography, geology, soil and soil cover, and the climatic conditions of these two counties are fully described elsewhere in this report.

The two counties have the approximate shape of an irregular quadrilateral with the western portion of its southern boundary extending westerly from the mouth of the Monocacy River along the Potomac River for about 15 miles, with Point of Rocks at about the center. From the Potomac River, the area extends northerly and easterly to the Pennsylvania-Maryland line, where it is about 39 miles in width. The total area is 1,110 square miles, nearly one half that of the State of Delaware. The area of Frederick County is 663 square miles, that of Carroll County is 447 square miles. All of Frederick County is tributary to the Potomac River, as also is Carroll County except its eastern part which is tributary to the Patapsco River and Gunpowder Falls. The entire area, therefore, is part of the Chesapeake Bay drainage.

The principal streams of this region are the Potomac River along the southern and southwestern boundary; Cococtin Creek and Monocacy River, which flow directly into the Potomac River; Gunpowder Falls, which crosses the northeast corner of the county; and the North and South Forks of the Patapsco River, which form the eastern boundary and the western half of the southern boundary, respectively, of Carroll County and are tributary to Chesapeake Bay through the Patapsco River. The more important streams and their drainage areas are listed in the following table.

STREAMS IN CARROLL AND FREDERICK COUNTIES[1]

Potomac River Basin

Stream	*Drainage area square miles*	
Catoctin Creek	121	
Broad Run	16.0	
Tuscarora Creek	20.5	
Monocacy River	970	742*
Ballinger Creek	18.0	
Bennett Creek	66.1	

[1] Appendix A. Inventory of Streams in Maryland. Report of Water Resources Commission of Maryland, January, 1933.

Stream	Drainage area square miles	
Big Pipe Creek	108	
Bush Creek	33.7	
Carroll Creek	18.6	
Double Pipe Creek	192	
Fishing Creek	18.2	
Hunting Creek	42.2	
Israel Creek	33.2	
Linganore Creek	88.4	
Little Pipe Creek	76.5	
Owens Creek	39.8	
Piney Creek	35.5	28.0*
Toms Creek	88.8	29.6*
Tuscarora Creek	16.8	
Patapsco River Basin		
North Branch Patapsco River	171	
Beaver Run	16.2	
West Branch Patapsco River	20.8	
East Branch Patapsco River	21.1	
Morgan Run	44.6	
South Branch Patapsco River	85.7	
Piney Run	18.2	
Gunpowder Falls	350	339*

* In Maryland.

GAGING STATIONS IN FREDERICK AND CARROLL COUNTIES

Records of the flow of streams in these two counties have been obtained by the United States Geological Survey in cooperation with the State of Maryland and Maryland municipalities at the following gaging stations.

Potomac River Basin

Station	Drainage area	Records*
1. Potomac River at Point of Rocks	9,651	1895–
2. Chesapeake & Ohio Canal near Point of Rocks	—	1932–1935
3. Catoctin Creek near Jefferson	111	1928–1931
4. Monocacy River at Bridgeport	174	1942–
5. Monocacy River at Ceresville near Frederick	665	1896–1930
6. Monocacy River at Jug Bridge near Frederick	817	1930–
7. Owens Creek at Lantz	5.70	1931–
8. Linganore Creek near Frederick	82.3	1931–
Patapsco River Basin		
9. North Branch Patapsco River near Reisterstown	91.0	1927–
10. North Branch Patapsco River near Marriottsville	165	1929–
11. Piney Run near Sykesville	11.4	1931–

* Stations with one date are still in operation.

Records for the mean daily and monthly flow for each of these gaging stations are published annually in the U. S. Geological Survey water-supply papers. Records of the maximum, mean, and minimum monthly flow and runoff per square mile in cubic feet per second and in million gallons per day for these stations from the date of establishment to September 30, 1943, are published in Bulletin No. 1, Department of Geology, Mines, and Water Resources, State of Maryland: "Summary of Records of Surface Waters of Maryland and the Potomac River Basin," 1944. This publication includes a map of Maryland which shows the location of the gaging stations in Frederick and Carroll Counties as well as of the other gaging stations in Maryland and the Potomac River Basin. An analysis of these records, especially of the Monocacy Run records, was published by the Department of Research and Education.[2]

The records of flow for the Potomac River at Point of Rocks and for the Monocacy River near Frederick are nearly 50 years in length and are among the longest continuous records of stream flow in the United States. They are of value in the studies of trend of climatological conditions, as well as for use in the design and construction of works for the regulation and control of floods, and for other purposes. Records at the Point of Rocks station indicate the runoff of the 9,650 square miles above the gaging station, but should not be considered as indicative of the runoff from Frederick and Carroll Counties, except in a very general way.

The mean annual runoff of the streams in these two counties, based on the records of the gaging stations with the longer records, excluding the Point of Rocks station, varies from about 650,000 gallons to 900,000 gallons per square mile per day. The minimum annual runoff is 260,000 and the maximum 2,100,000 gallons per square mile per day. It is, therefore, evident that if sufficient storage capacity can be provided there is an ample supply of surface water for domestic and industrial uses in these counties.

GROUND-WATER RESOURCES

BY

ROBERT R. BENNETT

No detailed ground-water investigation has been made in Frederick and Carroll Counties, but the available records of water wells and the published geologic maps afford a basis for analyzing the general features of the occurrence of ground water. The records of wells were compiled intermittently in the past by the Maryland Geological Survey. In 1944 a few additional well records were collected by the writer. General information on the occurrence of ground water in Frederick and Carroll Counties was published in 1918.[3]

The available records generally contain reported information on the depth and the yield of wells. The reported depth probably is correct to within a few feet, but the reported yield may not represent the maximum yield of the well. Wells reported

[2] Singewald, Joseph T., Jr., Maryland Stream Flow Records, Department of Research and Education, Solomons Island, Md., Educational Series No. 9, May, 1945.

[3] Clark, W. B., Mathews, E. B., and Berry, E. W., The surface and underground water resources of Maryland including Delaware and the District of Columbia. Maryland Geological Survey Special Publication, Vol. X, Part II, 1918.

to yield 5 to 20 gallons a minute are used mostly for domestic purposes which require only a few gallons of water a minute. Thus the reported yield of many of the wells may represent only the capacity of the pumps installed in the wells. Reported yields of more than 20 gallons a minute probably more nearly represent the maximum yield of a well, as wells yielding more than 20 gallons a minute ordinarily are used for industrial purposes or public supply. The statistical analysis of the reported yields and depths for various types of water-bearing rocks, given in this chapter, should be used only as a general guide to the productiveness of the water-bearing rocks.

RELATION OF GEOLOGY TO GROUND-WATER RESOURCES

Frederick and Carroll Counties form parts of two physiographic provinces, the Blue Ridge province in the extreme western part of the area and the Piedmont province in the remainder of the area. The boundary between the two provinces is at the foot of Catoctin Mountain in western Frederick County. In western Frederick County the Blue Ridge province is underlain by pre-Cambrian and lower Cambrian rocks consisting, for the most part, of basalts and quartzites. These rocks are relatively resistant to erosion and form rather rugged hills or mountains. The Piedmont province is divided into two regions, the Eastern Division and the Western Division, which are separated by Parrs Ridge. Parrs Ridge extends in a northeasterly direction across the western part of Carroll County.

In general the Western Division of the Piedmont province is underlain by pre-Cambrian schists and phyllites, Cambrian and Ordovician limestones, and Triassic shales and sandstones. The limestones of Cambrian and Ordovician age and the shales and sandstones of Triassic age occur in central and northcentral Frederick County and form a relatively low-lying gently rolling land surface known as Frederick valley. The Eastern Division of the Piedmont province is underlain mostly by schist and is characterized by a terrain with moderate relief.

The rocks in Frederick and Carroll Counties contain many openings or voids, which range from microscopic size to rather large passageways. The openings or voids in rocks are both primary and secondary. Primary openings were formed contemporaneously with the formation of the rock; secondary openings were formed after the formation of the rock. In this area nearly all of the openings in the rock are of secondary origin. The only important primary openings probably are in some of the sandstone beds of Triassic age.

The secondary openings in the rocks in this area were formed principally by structural movement which caused the rocks to break. These fractures allowed water to enter the openings and circulate, hence many of the openings were enlarged by weathering. In the more soluble rocks such as limestone or marble the circulation of water enlarged the openings by solution.

The amount of water that can be stored in a rock depends on the porosity which is the percentage of the total volume of the rock that is occupied by openings. In Frederick and Carroll Counties the degree of porosity is determined largely by the number and size of the secondary openings in the rocks. The percentage of the rock occupied by these openings generally is small. Hence the porosity of the water-bearing rocks in this area is generally low.

Although porosity indicates the quantity of water that a rock can hold it does not indicate how much water a rock may yield to wells. The yield of wells is more directly related to the permeability, which may be defined generally as the rocks' capacity for transmitting water. Permeability and porosity are only loosely related. Thus silt or clay may have as high a porosity as coarse sand or gravel, but the permeability of the silt or clay would be much smaller than that of coarse sand or gravel. Therefore, silt and clay would transmit less water. Furthermore in the minute openings in silt or clay the water is held against the force of gravity by the strong force of molecular attraction so that only a small percentage of the total water held can be drained and made available to pumping wells. In rocks containing large openings the molecular attraction is small and a large part of the water in the rock can be drained. The percentage of water per given volume of rock that can be drained by gravity is called the effective porosity or specific yield.

Ground water in Frederick and Carroll Counties is derived almost entirely from precipitation. The precipitation either runs off into streams, evaporates, transpires through vegetation, or percolates into the ground. The percentage of each is variable and is dependent on several factors such as the type, quantity, and intensity of the precipitation, topography, character of the soil, and type of weather that prevails after precipitation falls.

A part of the precipitation that percolates into the ground reaches the water table, which is the upper surface of the saturated zone of rocks. Most of the water is added to the ground water in the areas between the streams. The ground water moves very slowly from these areas to the streamways where it is discharged in the form of seeps or springs. Hence the water table generally is an undulating surface that is higher in the interstream areas.

In general the height of the water table is closely related to the amount of precipitation, although several other factors also play an important part in the fluctuations of the water table. For example, if the moisture in the soil is depleted by evaporation and transpiration during prolonged dry periods, the water from rains must replenish the soil moisture before water can move downward to the water table. In the winter the frozen ground is relatively impervious and relatively little water reaches the water table. On the other hand, the consumption of water by vegetation nearly ceases during the winter.

It is probable that the position of the water table is highest in the spring months after the soil has thawed and before transpiration begins drawing large quantities of water. In Frederick and Carroll Counties the amplitude of the fluctuations of the water table is probably rather large as the rocks are not capable of storing large quantities of water. Therefore during prolonged dry periods the water table may decline so low that some shallow wells will be dry and other wells and springs will decrease materially in yield. Reports have been persistent that the yields of wells and the discharge of many springs have decreased during the past several years. As no observation wells have yet been established in the area, the causes of the decrease are not known. It is possible that the precipitation, although nearly normal, may have been distributed poorly for recharge.

The geology largely controls the occurrence of ground water in any area. This is especially true in Frederick and Carroll Counties where the geologic structure is complex. In their original state nearly all of the rocks in this area were dense and practically impervious, but structural movement formed fractures or joints that allowed water to circulate in the rocks. The type of fractures and joints that have been formed is somewhat dependent on the type of rock. For example, in many places the fractures in the Triassic shales are numerous and closely spaced in contrast to the fractures in the hard crystalline rocks. The areal outcrop of the different rocks has been greatly affected by structural movement. This is well shown by the abrupt termination of the Triassic rocks at the Triassic border fault at the foot of Catoctin Mountain.

The geologic structure in Frederick and Carroll Counties is such that no large artesian basins have been formed, however, locally some water may occur under artesian conditions.

The distribution of the rock formations as they relate to the occurrence of ground water is such that Frederick and Carroll Counties may be divided into the following four rather ill-defined areas:

1. The area of pre-Cambrian and Cambrian crystalline rock in the Blue Ridge province in the western part of Frederick County. This area is underlain mostly by basalt and quartzitic rocks.

2. The belt of Triassic shales and sandstones in the Piedmont province in the central and the northcentral part of Frederick County, and the northwestern part of Carroll County.

3. The belt of Cambrian and Ordovician limestones in the Piedmont province in the central part of Frederick County.

4. The belt of pre-Cambrian and Cambrian crystalline rocks in the Piedmont province in the eastern part of Frederick County and nearly all of Carroll County. This area is underlain chiefly by schist, phyllite, and basalt. Locally it is underlain by marble and limestone.

GROUND WATER IN THE BLUE RIDGE AREA

The area of pre-Cambrian and Cambrian crystalline rock in the western part of Frederick County is characterized by high rugged hills and narrow deep valleys. The rocks consist mostly of quartzite and basalt and in general have not been deeply weathered.

Relatively few wells have been drilled as numerous springs and seeps occur in the area. Most of the springs discharge only a few gallons of water a minute. The source of the water from the springs and wells is from local precipitation, hence the discharge of the springs and the yields of many of the wells decrease materially during prolonged dry periods.

The few available well records indicate that wells from about 100 to 200 feet deep generally yield from 5 to 10 gallons a minute. However at Brunswick a well, 315 feet deep, was reported to yield 100 gallons of water a minute. Another well at Brunswick, drilled in 1912 to a depth of 160 feet, was reported to yield about 65 gallons a minute when drilled. The water was encountered at a depth of 123 feet.

Nearly all of the ground water in this area occurs in the fractures and joints in the rocks, or in the disintegrated or weathered rock near the surface. Inasmuch as the size and number of fractures generally decrease with depth, it would not seem advisable to drill water wells deeper than 300 feet. If possible wells should be located where the land surface is gently rolling, as in the rugged sections the water in the rocks is drained readily by the deeply-cut valleys.

The public water supplies obtained from ground-water sources, in this area, are at Brunswick, Braddock Heights, Middletown, and Myersville. All of these towns obtain their water supply from springs. The estimated daily water consumptions are about 200,000 gallons at Brunswick, about 15,000 gallons at Braddock Heights, and about 65,000 gallons at Middletown. Although Emmitsburg is outside of this area, it obtains part of its water supply from springs in the Catoctin Mountains.

The following table shows ranges of pH, alkalinity, hardness, and iron of the spring water used for public supplies in this area:[4]

(Except for pH, all results are in parts per million)

Location of public supply	pH	Alkalinity	Hardness	Iron
Brunswick	6.8–6.9	5–21	2–28	0–0.4
Braddock Heights	6.0–6.3	22–27	33–44	0
Middletown	5.9–6.1	23–25	30–33	0–0.3
Emmitsburg	6.2–6.6	11–17	4– 6	0–0.1
Myersville	5.8–6.7	5–14	2–13	0–0.2

GROUND WATER IN THE AREA OF TRIASSIC ROCKS

The area of Triassic rocks in the central and north-central part of Frederick County and the northwestern part of Carroll County is characterized by a relatively low-lying gently rolling land surface. The Triassic strata are composed chiefly of shale and sandstone, and many of the sandstone beds are well cemented and practically impervious. Hard dense igneous rock in the form of dikes and sills has intruded the Triassic strata in some places.

The following table summarizes the records of the depths and yields of wells in the area of Triassic rocks:

Summary of reported yields of wells in Triassic rocks

	Number of wells, with range in depth, in feet			
	100 feet or less	100–200	200–300	Total
2 g/m or less	9	9	1	19
2+ to 5 g/m	19	13	1	33
5+ to 20 g/m	15	19	4	38
20+ to 50 g/m	0	4	0	4
More than 50 g/m	0	2	0	2
Total	43	47	6	96

[4] All information on the public water supplies given in this chapter was furnished by the Maryland State Department of Health.

The preceding table indicates that the wells generally are less than 200 feet deep and yield from 2 to 20 gallons a minute. However a well at Taneytown, 150 feet deep, is reported to have yielded 110 gallons a minute. The five wells that supply water for Taneytown are reported to yield a total of 350 gallons of water a minute.

Although considerable ground water probably is contained in the porous sandstone beds, it is likely that ground water also occurs in the numerous small fractures and joints in both the sandstone and shale beds. In general ground water probably is more evenly widespread than in the crystalline rock areas and the probability of drilling a "dry hole" is small. The igneous rock in the form of dikes and sills in the Triassic strata probably affects the movement of ground water in those strata. The igneous rock probably would yield less water than the sediments.

The only public water supply obtained from wells in this area is at Taneytown; however, when necessary the Emmitsburg public supply utilizes wells to augment the springs. The estimated daily water consumption at Taneytown is about 150,000 gallons a day.

The range in pH, alkalinity, hardness, and iron of the ground water from the Taneytown wells is shown by the following table:

(Except for pH, all values are in parts per million)

Location	pH	Alkalinity	Hardness	Iron
Taneytown	6.9–7.5	111–129	125–127	0.–0.4

GROUND WATER IN THE FREDERICK VALLEY LIMESTONES

The area of Cambrian and Ordovician limestones in the central part of Frederick County forms a relatively low-lying level land surface. This area is principally a farm area, and many wells have been drilled for farm or domestic use. Some springs occur on the slopes along streamways, and some of the springs have a large discharge.

The following table gives a summary of the depths and yields of wells drilled to the limestone in central Frederick County:

Summary of reported yields from wells in Cambrian and Ordovician limestones in central Frederick County

	Number of wells with range in depth, in feet				
	100 feet or less	100–200 feet	200–300 feet	Over 300 feet	Total
2 g/m or less	5	2	0	0	7
2+ to 5 g/m	4	2	0	0	7
5+ to 20 g/m	7	4	1	0	12
20+ g/m to 50 g/m	3	2	2	5	12
Over 50 g/m	5	1	0	3	9
Total	24	11	3	8	46

This table indicates that the wells are generally less than 200 feet deep. The reported yields vary considerably but ordinarily range from 5 to 50 gallons a minute.

A well at Thurmont, 1,000 feet deep, yielded 125 gallons a minute with a drawdown of about 35 feet. At Walkersville the well used for public supply is 65 feet deep and yields about 80 gallons a minute.

A well drilled at Camp Detrick, about 1 mile northwest of Frederick, to a depth of 800 feet was reported to yield 38 gallons a minute with a pumping water level of 220 feet.

A well drilled to a depth of 61 feet in Frederick was reported to yield 100 gallons a minute. It was reported that a crevice was encountered at a depth of 61 feet. Two wells, 996 and 1,140 feet deep, drilled for the City of Frederick, 4 miles west of Frederick, yielded a total of 70 gallons of water a minute.

The yield from wells in the Cambrian and Ordovician limestones is very erratic, but the yields may be greater than in the crystalline rocks. The yield from a well in the limestone depends on the number and size of openings penetrated, but the possibility of encountering larger openings is better in the limestone than in rocks such as phyllite, schist, and basalt. Limestone is somewhat soluble and the ground water that circulates in the fractures and joints dissolves some of the limestone thereby forming larger openings.

The only public water supplies from ground water in this area are at Thurmont and Walkersville. The Thurmont supply is obtained from wells, and the Walkersville supply is obtained from both wells and springs. The estimated daily water consumption is about 170,000 gallons at Thurmont and about 100,000 gallons at Walkersville.

The following table gives the ranges of pH, alkalinity, hardness, and iron of the water from the public supplies:

(Except for pH, all values are in parts per million)

Location	pH	Alkalinity	Hardness	Iron
Thurmont				
(Well, depth 1,000 feet)	6.0–6.5	17– 24	2– 30	0.06–2.2
Walkersville				
(Well, depth 100 feet)	7.1–7.8	166–181	196–208	0 –0.02
(Well, depth 105 feet)	6.0	18– 24	22– 35	0.04–0.2

GROUND WATER IN THE EASTERN PIEDMONT AREA

The area of pre-Cambrian and Cambrian crystalline rocks in the eastern part of Frederick County and nearly all of Carroll County is characterized by terrain of moderate relief. The area is underlain chiefly by schist, phyllite and basalt; but marble or limestone occurs locally.

In general the rocks have been deeply weathered, but in some places the surface is rocky. Numerous springs issue along the streams and hillsides, and many of these springs are used for public supplies and domestic purposes. Most of the springs discharge only a few gallons a minute. The following table summarizes the depths and yields of wells ending in schist, phyllite and basalt:

Summary of reported yields from wells in schist, phyllite and basalt

	Number of wells with range in depth, in feet				
	100 feet or less	100–200	200–300	Over 300 feet	Total
2 g/m or less	9	7	2	3	21
2+ g/m to 5 g/m	26	10	1	1	38
5+ g/m to 20 g/m	39	12	2	4	57
20+ g/m to 50 g/m	4	4	3	3	14
Over 50+ g/m	2	4	1	3	10
Total	80	37	9	14	140

This table shows that a majority of the wells are less than 100 feet deep and yield from 2 to 20 gallons a minute. In the 140 well records only 14 wells are deeper than 300 feet. Only 10 wells are reported to yield more than 50 gallons a minute.

In 1936, a well at Hampstead, drilled to a depth of 137 feet, yielded 56 gallons a minute with a drawdown of about 25 feet. Another well at Hampstead is 407 feet deep and yields 17 gallons a minute with a pumping level of 132 feet.

The marble and limestone seem to yield larger quantities of water to wells than the other rocks. The following table summarizes the records of wells ending in marble and limestone:

Summary of reported yields from wells in marble and limestone

	Number of wells with range in depth, in feet				
	100 feet or less	100–200 ft.	200–300 ft.	Over 300 feet	Total
2 g/m or less	2	2	0	0	4
2+ g/m to 5 g/m	2	0	0	0	2
5+ g/m to 20 g/m	2	0	0	0	2
20+ g/m to 50 g/m	6	0	1	0	7
Over 50 g/m	2	1	0	2	5
Total	14	3	1	2	20

This table indicates that the majority of the wells yield more than 20 gallons a minute and are less than 100 feet deep.

A well drilled, at Westminster, to a depth of 200 feet was reported to yield 150 gallons a minute. A well at the B. F. Shriver Company, Westminster, is 787 feet deep and is reported to yield 300 gallons a minute with 6 feet of drawdown after 8 hours of pumping. The static water level was reported to be about 12 feet below the land surface. Wells drilled at Union Bridge are reported to have high yields. One well, 170 feet deep, is reported to yield 400 gallons a minute. Probably all of these higher yielding wells draw water from solutional openings in the limestone or marble.

Several public water supplies use ground water in this area. Manchester and New Windsor utilize springs, but the supply at Manchester is increased, when necessary, by a well. The public supplies at Hampstead, Union Bridge, and Mt. Airy are obtained from wells. The estimated daily water consumptions are 100,000 gallons at Union Bridge, 30,000 gallons at Mt. Airy, 35,000 gallons at Manchester, 25,000 gallons at Hampstead, 35,000 gallons at New Windsor.

The following table gives the ranges of pH, alkalinity, hardness, and iron of the water in the various public supplies.

(Except for pH, all values are in parts per million)

Location	pH	Alkalinity	Hardness	Iron
Manchester				
(Springs)	5.8–6.9	10– 45	27–154	0.0–1.7
(Well)	5.8–6.8	10–118	27–208	0.0–6.5
New Windsor				
(Springs)	6.0–6.2	10– 20	12– 32	0.0–0.4
Hampstead				
(Well, depth 150 feet)	4.9–7.8	7– 22	8–112	0 –3.2
(Well, depth 204 feet)	5.5–6.0	14– 23	71–105	0 –0.4
(Well, depth 407 feet)	6.0–7.5	13– 85	26–136	0 –0.5
Mt. Airy				
(Well, depth 95 feet)	6.0–6.2	10– 20	12– 32	0 –0.4

WELL RECORDS IN CARROLL AND FREDERICK COUNTIES

The following table gives the records of wells, in Frederick and Carroll Counties, on file in the Maryland Department of Geology, Mines and Water Resources. These records do not include all of the important wells, but they provide useful information on the occurrence of ground water.

WATER WELL RECORDS IN CARROLL AND FREDERICK COUNTIES

Location	Owner or name	Date drilled	Depth	Diam.	Reported yield	Remarks
			feet	*inches*	*gal. a min.*	
Adamstown	Thomas & Co.	1939	400	8	100	
do	do	1925	150	8	100	
do	—	—	99	—	—	Cased to 16 feet
do	R. H. Padgett	1913	38	—	—	Cased to 12 feet
do	C. F. Carlin	1916	36	6	15–20	Cased to 15 feet
do	Canning Co.	1925	150	6	30	
do	Frederick County	1924	48	—	—	School well
do	Henry H. Haynes	—	100	6	1	
Araby, 1 mile south of	Julia Young	—	162	6	5	
Barrett	A. B. Wetzel	1929	72	—	—	
Barrett, 0.5 mile northeast of	Sam Smith	1928	70	6	8	
Bartonsville	Edward Laird	—	86	6	5	
Blocks School	Henry Wolf	1922	80	6	15	
do	George Myers	1926	105	6	15	
Braddock Heights	Braddock Heights Water Supply	—	100	—	25	
Braddock Heights, 1.3 miles south of	Colliers	—	80	—	8–10	
Braddock Heights, 1 mile east of	Cornelia Ross	1911	192	6	8	
Bridgeport	Wilber Stull	1929	94	6	1	
do	Samuel Stone	1929	80	6	6	
Bruceville	Creamery	1919	77	6	20	
do	Frank Sneeringer	1925	68	6	3.5	
Brunswick	Brunswick	1908	315	8	100	Smaller supply, 25 g.p.m., encountered at 230 feet
do	Canning Co.	—	200	6	50	Well abandoned
do	Ice Plant	1912	160	6	65	Yield later decreased to 40 gal. a min.
Buckeystown	W. G. Baker	1890	70?	6	—	Cased to 8 feet
do	James Hilton	1929	74	—	4	
do	St. Josephs Church	—	65	60	—	Dug well
do	Industrial School	1904?	110	6	5	Principal supply at 90 feet

Burkittsville	Frederick County	1914	40	—	—	School well
Catoctin, 1.0 mile north of	Frederick County	1941	56	—	—	do
Carrollton	Mr. Hughes	1934	142	6	48	
Cascade	Md. National Guard	1931	300	8	50	Principal supply at 295 feet
Ceresville	Edward Trynon	—	125	6	—	Yield reported to be large
Ceresville, 0.5 mile west of	Miller Cummins	—	145	6	—	Well reported to go "dry" in drought
do	W. J. Hahn	—	155	6	—	
do	do	—	63	6	—	Supply adequate for domestic use
Cherrytown	F. H. Leppo	1926	80	6	1	
Church Hill	Geo. E. Cook	1909	44	6	0.5	Cased to 5 feet
Clemsonville	Geo. Cox	1931	4	6	25	Well at site of spring, that ceased flowing
do	Ezra Nusbaum	1931	349	6	8	
Creagerstown	Chas. Kolb	1923	145	6	10	
do	Frederick County	1926	80	—	—	School well
do	Harry Lower	1913	117	—	8	Cased to 12 feet
do	Dr. G. Devilbliss	—	103	6	—	Water contains iron
do	Isaac Hanky	1913	161.5	6	8	Water in red rock
Daniel	Ray Brown	1932	87	6	10	
do	Amos Shipler	1931	69	6	10	
Daniel, 0.8 mile west of	Chas. Flemming	1931	52	6	5	
Daniel, 0.5 mile south of	Russell Grimes	1932	85	6	10?	
do	do	1932	140	—	0	"Dry" well
Dennings	Walter Browner	1921	90	6	2	
Detour	L. F. Miller & Son	1930	161	6	7	
do	Lillie Waybright	1925	144	6	10	
do	J. A. Mitten	1926	78	6	2	
do	Dairy	1923	299	$6\frac{1}{2}$	20	
Detour, 1 mile northwest of	N. C. Dorcas	—	125	—	5	Water reported to be hard
Elderburg, 1.0 mile east of	Parks Clark	1932	88	6	10	
Ellerton	Elias Routson	—	79	6	8–10	Well had a flow when drilled
Emmitsburg	Harvey Miller	1928	157	$5\frac{3}{4}$	5.5	
do	Alford Stonesifer	1926	110	6	3	

WATER WELL RECORDS IN CARROLL AND FREDERICK COUNTIES—*Continued*

Location	Owner or name	Date drilled	Depth	Diam.	Reported yield	Remarks
			feet	*inches*	*gal. a min.*	
Emmitsburg—*Continued*						
do	Walters & Scott	1923	70	6	5	
do	Cover Lumber Co.	1923	102	6	1.5	
do	Frank Wivel	1919	95	6	16	
do	Sisterhood Tenant House	1919	65	6	2.5	
do	J. O. Kremp	1919	80	6	2.5	
Emmitsburg, 2.0 miles southwest of	D. F. Ruddy	1930	102	6	10	
Feagaville, 1.0 mile north of	W. D. Zimmerman	1932	106	6	3	Cased to 16 feet
Finksburg	Distilling Co.	1934	335	8	25	Well 2
do	do	1934	—	8	—	Well 3
do	do	1923	469	8	40	Well 1
Fountain Rock, 0.8 mile south of	S. E. Brown	1932	169	6	15	Temp. 52° F.
Foxville	Frederick County	1928	55	—	—	School well
Frederick	Joseph Himes	1930	604	6	150	
do	Chestnut Farms Dairys	—	86–120	8	30–50	4 wells
do	Frederick City Packing Co.	1910	178	6	5–10	Water occurs in blue limestone
do	Walker Hill Dairy	1920	105	—	40	
do	Nicodemus Ice Cream Co.	1923	70	—	100	
do	G. G. Gosnell	1932	22	6	—	
do	Frederick County Products Co.	1912	96	8	100	Water occurs in blue limestone
do	do	1911	123	4	60	
do	John Favorite	—	76	—	1	
do	Everedy Co.	1941	61	8	100	Water unfit for drinking
Frederick, 1 mile south of	Lewis Burgler	—	68	6	1	
Frederick, 1.5 miles south of	Charles Trail	1911	200	6	50	
Frederick, 2 miles southeast of	R. Harder	1931	100	6	10	
Frederick, 1.5 miles north of	Ebert Ice Cream Co.	1930	30	8	30	
do	do	1930	235	8	30	Principal supply at 200 feet

Frederick, 1.5 miles north of	Ebert Ice Cream Co. *Continued*	1930	350	8	30	
do	do	1930	735	8	30	Principal supply at 300 feet
do	do	1930	200	8	80	Principal supply at 60 feet
do	do	1930	68	8	50	
Frederick, 2 miles northeast of	Sam Rosenstopp	—	90	—	7	
Frederick, 3 miles east of	John Wrenn	—	70	6	5	
Frederick, 3.0 miles north of	T. P. Jones	—	67	6	7	
Frederick, 3.5 miles northwest of	City of Frederick	1844	996 1,140	—	70	Two wells. Wells abandoned
Frederick, 2.5 miles west of	Catoctin Country Club	—	144	8	40	
Frederick, 2.0 miles west of	Walter Feager	—	70	6	5	
Frederick, 1.5 miles southwest of	Otis King	1932	100	6	10	
Frederick, 2 miles south of	Charles Hoffner	—	153	—	1	
Frederick, 2 miles southeast of	Thomas J. Altman	—	50	—	5	
Frederick, 1.0 miles northwest of	Camp Detrick	1944	800	—	38	Not used. Pumping water level 221 feet
Freedom	H. Hatfield	1932	90	6	15	Cased to 60 feet
do	De Vrise	1930	77	6	25	
Freedom, 1.7 miles northwest of	A. R. Wetzel	1933	42	6	10	
Freedom, 0.6 mile southeast of	Mrs. B. Wilson	1930	87	6	20	
Freedom, 1.8 miles northwest of	Ed. Wright	1931	97	6	—	
Frizzleburg	D. F. Haifley	1929	73	6	20	
do	Ed. Strevig	1929	42	6	10	
do	Glenn Wareheimer	1930	161	6	10	
do	Joseph Bostien	1928	75	6	1.5	
do	Ross Wilhide	1930	168	6	6	
do	K. Dickensheets	1931	58	$5\frac{5}{8}$	3	
do	S. E. Hiveby	1931	90	6	3	
do	Lewis Wantz	1932	62	6	4	
do	J. W. Warhimer	1932	102	6	1.5	
Gamber	Carroll County	—	80	—	—	School well
Graceham	J. C. Pyle	—	80	4	—	

WATER WELL RECORDS IN CARROLL AND FREDERICK COUNTIES—*Continued*

Location	Owner or name	Date drilled	Depth	Diam.	Reported yield	Remarks
			feet	*inches*	*gal. a min.*	
Greenmount	Canning Co.	1924	90	6	—	
do	do	1939	120	6	—	
do	do	1929	110	6	18	Water occurs at 68 feet, top of hard rock
Hampstead	Rev. Brown	1931	82	6	5.5	
do	J. O. Snyder	1931	85	6	7.5	
do	Carroll County	—	110	—	—	School well. Not in use
do	Bankert Bros.	1941	285	8	55	
do	I. S. Leister	1932	72	6	4.5	
do	C. T. Mathews	1931	132	6	7.5	Water occurs at depth of 76 feet
do	C. H. Sapp	1933	79	6	14	Cased to depth of 28 feet
do	E. J. Hubb	1932	85	6	7.5	
do	Hampstead	1936	137	—	56	Pumping water level 65 feet
do	do	1936	407	—	17	Pumping water level 132 feet
do	Canning Co.	1905	135	—	60	
do	do	1934	125	—	50	Water occurs at depths of 32, 68, and 108 feet
Harney	J. M. Reaver	1932	96	6	3.5	
do	M. B. Wheeler	1930	106	6	11	
do	Mrs. M. Witherow	1926	84	6	1	
Highfield	Children's Hospital	—	216	6	20	
do	Western Md. R.R.	1918	347	—	—	
do	do	1937	104	8	—	
Hoffmans Mill	Dr. Shanner	1929	85	6	1.5	Cased to depth of 25 feet
Hopeland, 1 mile northwest of	A. Kreb	—	100	6	10	
Houcksville	Dodson Elsrowe	1931	81	6	5.5	Cased to depth of 24 feet
do	Wesley Church	1933	72	6	9.5	Cased to depth of 33 feet
Jefferson	Frederick County	1926	71.5	—	—	School well
do	Doty	—	62	6	—	Cased to 40 feet

Jefferson *Continued*	L. E. Summers	1910	60	6	15	Cased to 53 feet
do	H. S. Summers	1915	67	6	—	Cased to 12 feet
Jewsburg	John Dwilt	1915	140	6	3.5	
do	Mrs. Wm. Ziles	1925	82	6	20	
Johnsville	Alton Grem	—	114	6	2.5	
do	Frederick County	1920	63	—	—	School well
Kemptown	J. W. Williams	—	92	6	—	
Kemptown, 0.5 mile northwest of	M. Mount	—	119	—	5	
Kemptown, 1.5 mile northwest of	E. Watkins	1923	90	—	5	
Keymar	A. W. Fesser & Co.	1924	194	6½	40	Water encountered at 188 feet
do	do	1925	100	6	4.5	
do	M. F. Wiley	1926	53	6	5.5	
do	B. D. Mehring	1930	170	6	10	
do	L. Hahn	1930	88	6	4.5	
do	Upton Mehring	1931	60	6	3	
do	do	1932	100	5⅝	5	
do	Geo. Koontz	1930	122	6	5	
do	M. W. Bell	1922	165	6	2	
do	R. Lowman	1922	83	6	2	
do	W. F. Cover	1920	75	6	6	
do	Edw. Sharrets	1919	101	6	3	
Keysville	Peter Baumgartner	1926	80	6	5.5	
do	Picnic grounds	—	89	6	5	
Keysville, 1.0 mile south of	C. W. Roof	1932	112	6	4	
Knoxville	J. A. Swope	—	47	6	—	
do	Horsey Distilling Co.	1907	220	8	—	"Dry" hole
Kump	Henry Erb	1928	52	6	2.5	
Ladiesburg	Frank Habough	1925	82	6	20	
Lander, 0.7 mile east of	Mr. White	—	135	6	5	
Lewistown	Frederick County	1926	100	—	—	School well
Lewistown, 2.5 miles west of	C.C.C. Camp	1939	698	6	3	
Libertytown	R. W. Wright	—	32	6	—	Water occurs at depth of 21 feet
do	Catholic Church	—	75	—	—	
do	Frederick County	1927	180	—	—	School well
do	do	1941	95	—	—	do

WATER WELL RECORDS IN CARROLL AND FREDERICK COUNTIES—*Continued*

Location	Owner or name	Date drilled	Depth	Diam.	Reported yield	Remarks
			feet	*inches*	*gal. a min.*	
Libertytown, 2.3 miles south of	Chas. Jones	1920	69	6	5	
Limekiln	Wm. Moran	—	90	6	5	
Linwood	Jesse Willis	1925	117	6	1	
do	Theo. Haynes	1930	78	6	5	
do	Philip Selby	1931	80	6	6	
do	Mrs. J. S. Waltz	1896	75	72	—	Dug well. Water level ranges from 1 to 14 feet, depending on quantity of rainfall
Longcorner	Elmer Mollinix	1918	75	6	8	
Longcorner, 0.8 mile northwest of	G. Shell	1919	114	—	3	Principal supply at depth of 60 feet
Loys	W. G. Sprague	—	132	6	5	Water in red rock
McAleer	N. A. Fulton	1931	80	6	40	Cased to 14 feet
Manchester	Carroll County	—	120	—	—	School well
do	do	1933	80	6	7.5	Water occurs at 68 feet
do	Mr. Alborne	1930	80	6	14	Water occurs at 54 feet
do	C. Turner	1932	96	6	7.5	Water occurs at 84 feet
do	Manchester	—	645	8	5	Town well 3
do	do	—	150	8	4	Town well 1
do	do	—	410	8	10	Town well 2
do	do	—	310	8	30	Town well 4
Manchester, 3.0 miles north of	Farmers Coop.	1937	180	6	—	
Marriottsville, 0.7 mile northeast of	Mr. Flynn	—	95	—	12	
Mayberry	Arthur Copenhaver	1922	120	6	2.5	
Melrose	P. D. Gradman	1925	100	8	36	Cased to depth of 70 feet
Middleburg	Mrs. F. Littlefield	1928	102	6	3.5	
do	Frank Harbaugh	1930	210	6	2	
do	J. A. Grayster	1931	94	6	8	
do	G. C. Skipper	1931	210	6	3.5	
do	H. C. Putman	1930	97	6	6	
do	Jesse Reisler	1933	97	6	3.5	

Middlepoint, 1.0 mile southeast of	H. C. Delord	—	213	6	0	"Dry" when drilled
Middletown	Middletown Canning Co.	—	104	—	15	
do	So. Mountain Creamery Co.	1925	375	6	30	Static water level reported 60 feet below land surface
Monrovia	Canning Co.	—	54	—	5	
do	do	—	84	—	35	
Motters	Grant Long	1931	70	6	1	
Mt. Airy	M. G. Harrison	1900	78	6	—	
do	S. W. Stackhouse	1904	173	6	—	Yields 3 quarts of water hourly
do	do	1913	306	6	1	
do	Hotel	1883	40	6	—	Water occurs in "slate rock"
do	B. L. Dorsey	1907	48	6	7	Water occurs in "flint rock"
do	do	1893	94	6	—	
do	C. E. Harris	1910	65	6	—	
do	E. Mollinix	1918	85	6	7	
do	Asa Watkins	1927	96	6	4	
do	do	1927	111	6	5	
do	Canning Co.	1917	120	8	—	Well yields "4-inch stream" of water with drawdown of 50 feet
do	Milling Co.	1919	84	6	15	
do	Bank	—	78	—	5	
do	Kemp Norwood	—	113	6	4	
do	S. Gilbert	—	94	—	5	
Mt. Airy, 0.5 mile northwest of	Mt. Airy	1924	106	8	80	
do	do	1929	94	8	100	
Mt. Airy, 0.8 mile northeast of	Don Weiggler	—	136	—	—	
Mt. Airy, 0.5 mile south of	T. Watkins	1919	90	—	5	Two wells
do	do	—	54	—	10	
Mt. Pleasant	Sparrows Point Sewer Co.	1900	115	6	—	Cased to 10 feet
do	John H. Etzler	1903	74	6	—	Principal supply at 70 feet
do	C. T. Angleberger	1922	105	6	15	
do	Louis Lochman	—	83	6	2	
Mt. Union Church	John Starr	1931	96	6	5.5	
do	G. P. Buckay	1931	242	6	8	

WATER WELL RECORDS IN CARROLL AND FREDERICK COUNTIES—*Continued*

Location	Owner or name	Date drilled	Depth	Diam.	Reported yield	Remarks
			feet	*inches*	*gal. a min.*	
Mountville	Frederick County	1920	73	—	—	School well
Mount Zion	Keefer Motz	1931	123	6	6	
do	C. C. Eyler	1932	115	6	7	
Myersville	G. C. Eldridge	1911	167	6	5	Water has "mineral" taste
do	Mr. Smith	1889	115	6	—	Principal supply at 115 feet
New London	J. R. Brandenburg	1895	57	6	—	
do	Roy E. Long	—	186	$5\frac{5}{8}$	5	Cased to 24 feet
New Market	Church	1927	35	—	—	
do	Frederick County	1932	96	—	—	
do	Hudson Winebury	1906	38	6	—	
New Midway	Frederick County	1930	102	—	—	
do	New Midway School	1929	110	6	10	
New Windsor	New Windsor	1939	1,033	—	2	
do	Dr. Smeltsner & Son	1924	130	6	15	
do	Joseph Haines	1925	144	$5\frac{5}{8}$	20	
Oak Orchard	—	1925	304	6	1	Water occurs at depth of 70 feet
do	W. E. Dudder	1922	108	6	5.5	
do	P. T. Duelderer	—	112	$7\frac{1}{4}$	24	
do	L. A. Barnes	1922	30	$5\frac{5}{8}$	20	
Oklahoma	Allen Wilson	1930	112	6	10	
Oklahoma, 0.5 mile south of	Willie Ogden	1931	200	6	10	
Pearl	J. L. C. Bopst	—	72	—	—	
Plane No. 4	Harry Brown	1929	33	6	—	Not cased
Pleasant Valley	Packing Co.	do	80	6	22	Water occurs at 40 feet in "sand rock"
Piney Creek, 1.0 mile north of	C. B. Reaver	1933	90	6	3	
Point of Rocks	School Board	—	215	6	2	Crushed stone placed in bottom of well to keep out fine sand
do	B. & O. R.R.	1930	57	6	50	
Popular Springs	Arthur Burdette	—	52	6	—	

Ridgeville	Chas. Moxley	—	83	—	3	
do	Claude Brown	—	60	—	10	
do	C. Bennett	1918	84	6	5	
Rocky Ridge	Chas. Engler	1921	39	6	0.5	
do	Elmer P. Schildt	1923	93	6	5.5	
do	Chas. Barrick	1923	—	6	—	
do	Upton Mehring	1928	100	6	1	
do	Wm. Renner	1932	76	6	10	
do	James Angel	1931	152	6	2	
do	Frederick County	1927	48	—	—	School well
Sabillasville	do	1926	55	—	—	
Sam's Creek	Herbert Ecker	1922	65	5⅝	3.5	Water occurs in limestone
do	David Stem	1921	80	6	0.5	
do	Merton Engle	1925	203	6	3.5	
Sanatorium	Md. Tuberculosis Sanatorium	—	124	6	5	
do	do	1909	300	6	35	
do	do	1909	200	6	15	
do	do	1909	128	6	5	
Sandy Mount	Carroll County	—	120	—	—	School well
Silver Run	Wm. Frock	1923	50	5⅝	3.5	
do	Paul Fitz	1921	81	6	1.5	
do	C. I. Crower	1920	117	—	1	
do	do	1920	126	—	1	
do	do	1920	162	—	1	
do	do	1920	200	—	1	
do	do	1920	320	—	1	
do	A. W. Feeser Co.	1941	460	8	60	Static water level reported to be 30 feet below land surface
do	do	1930	205	8	40	
do	Geo. Schaffer	1927	144	6	0.5	
Stronghold	Gordon Strong	1929	59	6	24	Water in sandstone
Sykesville	State Hospital	1915?	500	6	22.5	
do	do	1915?	550	6	22.5	

WATER WELL RECORDS IN CARROLL AND FREDERICK COUNTIES—*Continued*

Location	Owner or name	Date drilled	Depth	Diam.	Reported yield	Remarks
			feet	*inches*	*gal. a min.*	
Sykesville *Continued*	State Hospital	1911	505	6	55	Two wells
do	—	—	107	—	9	
do	Carroll Co.	—	120	—	—	School well
do	State Hospital	1897	140	—	40	
do	Mrs. Harp	1930	88	6	10	
do	Crooks	1930	104	6	10	
do	Minnie Fillinger	1933	77	6	25	Cased to 40 feet
do	—	1912	100	6	9	
Taneytown	Walnut Grove School	1929	114	6	0.5	
do	do	1929	103	do	5	
do	Western Maryland Fairfield Dairy	1925	200	7½	25	
do	Taneytown	1925	150	8	60	
do	S. Nusbaum	1926	67	6	2.5	
do	G. R. Sauble	1927	250	6	15	
do	Jacob Neel	1927	118	6	20	
do	Ida Koontz	1930	130	6	7	
do	Wm. Erb	1930	117	6	2	
do	E. R. Rineman	1930	102	6	1	
do	R. L. Hahn	1931	85	6	5	
do	Wilbur Stinesifer	1931	95	6	0.5	
do	Anna Galt	1931	102	6	5.5	
do	Samuel Clingland	1932	130	6	4.5	
do	Arte Angel	1922	67	6	6	
do	Fair Grounds	1921	142	6	6	
do	Wm. Little	1921	99	6	10	
do	John Vaugn	1921	69	6	3	
do	Martin Conover	1920	63	6	4	
do	Chas. Maws	1920	52	6	16	

Taneytown *Continued*	Taneytown	1925	150	8	65	
do	David Nusbaum	1923	100	$5\frac{5}{8}$	1.5	
do	Reduction Plant	1920	202	6	8	
do	Taneytown	1927	150	8	110	
do	do	—	150	$5\frac{5}{8}$	50	
do	do	—	150	6	—	
do	Fred Shank	1923	99	6	2	
do	Ed. Fogle	1922	60	6	1	
Taneytown, 0.5 mile north of	Taneytown	—	280–362	1–8	350	Five wells
Taneytown, 1.0 mile southwest of	Elmer Shorb	1928	88	6	7	
Taneytown, 4.0 miles southwest of	Chas. Airling	1928	92	$5\frac{3}{4}$	1	
Taneytown, 3.0 miles southwest of	Mahlon Brown	1926	68	6	3	
do	Geo. Deberry	1926	68	6	6	
Taneytown, 2.0 miles southwest of	G. T. Harman	1931	103	6	1.5	
Taneytown, 3.5 miles southwest of	R. W. Hess	1930	183	6	4	
Taneytown, 2.5 miles south of	Mrs. Guy Ourand	1929	80	6	4.5	
Taneytown, 1.5 miles northeast of	G. V. Miller	1928	81.5	6	20	
Taneytown, 3.0 miles north of	Huber Spangler	1931	71	6	2	
do	Thomas Ecker	1931	124	6	2	
Taneytown, 1.5 miles southwest of	G. L. Harman	1932	123	6	10	
do	H. Deberry	1932	88	6	4.5	
do	Walter Diffendall	1932	115	6	10	
Taneytown, 2.5 miles south of	Russell Feeser	1932	118	6	4.5	
Taneytown, 2.5 miles southeast of	J. E. Hartzel	1925	163	6	6	
Thurmont	—	—	1,000	—	125	Drawdown of 38 feet
Toms Creek Church	James Mert	1919	62.5	6	1	
do	Emory Hahn	1919	—	6	—	
Trevanion	G. F. Gilbert	1925	60	6	2.5	
Troutville	Joseph Fox	1925	110	6	3	
do	N. E. Stitely	1923	39.5	6	4	
Tyrone	C. Wantz	1932	50	6	15	
Union Bridge	Charley Angel	1925	200	6	1	
do	Cement Co.	1926	85	6	25	
do	G. H. Pittinger	1922	76	6	1.5	

WATER WELL RECORDS IN CARROLL AND FREDERICK COUNTIES—*Concluded*

Location	Owner or name	Date drilled	Depth	Diam.	Reported yield	Remarks
			feet	*inches*	*gal. a min.*	
Union Bridge *Continued*	Union Bridge	1904	214	6	50	Water occurs in limestone
do	do	1904	50	6	50	Water occurs in gravel
do	do	1904	50	6	50	do
do	do	1904	464	6	300	Water occurs in limestone
do	do	1904	246	6	50	do
do	Abner Devilbis	1928	92	6	40	
Union Mills	B. F. Schriver & Co.	1926	399	6	10	
Uniontown	J. Dayhoff	1931	202	$5\frac{5}{8}$	1	
do	Board of Education	1931	103	6	10	
do	G. F. Gilbert	1931	34	6	10	
do	Guy Cookson	1923	53	6	15	
do	Carroll County	—	100	—	—	School well
Urbana	Zion Church	—	30	—	—	Yields small supply
do	St. Ignatius Church	—	65	—	—	
do	Frederick County	1928	90	—	—	School well
Urbana, 0.7 mile northwest of	G. R. Denis	—	60	6	10	
Walkersville	C. W. Ross	1903	69	6	—	Have pumped 6,500 gal. an hour for18 hours
do	Walkersville	1904	100+	—	150	Public supply well
do	Glade Valley Milling Company	1906	100?	6	60	Cased to 20 feet
do	Chestnut Farm Dairy	—	400	6	50	Principal supply at 70 feet. Temp. 62° F.
Walkersville, 0.7 mile northeast of	S. E. Rodruck	1931	72	6	10	
Watersville	W. Chaney	1918	112	6	2	
Westminster	M. Hames	1929	92	6	6	Water occurs in dark blue rock at 75 feet
do	Koontz Creamery	1940	74	8	300	
do	do	1908	100	6	35	Water occurs in limestone

Westminster *Continued*	Metal Foundry Co.	1912	90	—	40	Water occurs in limestone
do	Chas. Stamer	1926	80	6	10	
do	Borden's Ice Cream Co.	1940	200	8	150	Temp. 54° F.
do	Ice Company	1894	90	6	50	Water occurs in limestone
do	B. F. Shriver	1938	787	10–8	300	Drawdown of 6 feet
Winfield	Carroll County	—	300	—	—	School well
do	do	—	200	—	—	do
do	Chas. Barnes	1931	89	6	10	
Winfield, 0.5 mile west of	Walter Wright	1933	56	6	10	
Woodbine	A. Gaslein	1918	129	6	25	
do	Lee Condin	—	84	—	4	
do	Canning Co.	—	61	—	15	
do	do	—	118	—	15	Two wells
Woodbine, 0.8 mile northeast of	J. Pickett	—	78	—	5	
Woodbine, 1.0 mile north of	C. Goslin	—	90	—	5	
Woodsboro	Wm. F. Hoffman	1924	58.5	6	2	
do	C. W. Wills	1924	56.5	6	—	
do	Canning Co.	—	198	6	20	
do	Mr. Smith	—	52	6	2	
do	G. F. Smith	1924	100	6	7.5	
do	C. D. Kraus	—	126	—	2	
do	S. W. Barry	—	64	6	1.5	
do	Frederick County	1942	60	—	—	School well
Woodsboro, 0.5 mile northwest of	Williams Kuthors	—	198	5⅝	12.5	
Wolfsville	Wolfsville School	1931	200	6	5	
do	Frederick County	1920	150	—	—	School well
Wolfsville, 0.4 mile north of	Morgan Mille	—	65	6	5	Cased to 50 feet. Water has slight "sulphur" odor
Wolfsville, 0.25 mile north of	Michael Kline	1910	85?	5⅝	5	Cased to 25 feet. Water has slight "sulphur" odor
Yellow Springs	Dennis Lanehart	—	80	6	5	
do	D. H. Stone	—	80	6	5	Principal supply at 70 feet
do	C. N. Kehne	1933	78	6	5	Water has slight "sulphur" odor
do	D. F. Staley	—	71	—	—	Principal supply at 40 to 50 feet
Yellow Springs, 0.6 mile southwest of	Frank Kraill	—	100	6	1	

SOILS OF CARROLL AND FREDERICK COUNTIES

BY

F. G. LOUGHRY AND D. C. TAYLOR

Introduction

Soil may be considered as merely the surface layer of the land or it can be recognized as the basis of plant growth and agriculture. Both viewpoints will be combined in this chapter. Thought of as a feature of surface geology, the soil is a thin mantle of weathered material which comes from a wide variety of parent rocks and which has been modified in many respects by climate, vegetation, movement by wind and water, and other soil forming forces. In Frederick and Carroll Counties, soils in great variety have resulted from the combined action of all these factors. Several kinds of sandstone, shale, limestone, schist, quartzite and igneous rocks provide a varied material on which the soil forming processes operate. Steep slopes in part of the area have favored rapid removal of weathered products and prevented accumulation of deep soils. Elsewhere, deep soils have weathered from the underlying rocks on moderate slopes. Transported and mixed materials have been deposited along streams and at the foot of steep slopes, especially near South Mountain. Many soils mapped in the area are separated on the basis of parent geologic material, depth of soil, and mode of soil formation. Additional separations are based on stoniness, which is closely associated with the type of parent material. The presence of large stones on or near the surface is of great agricultural importance, as it hinders or even prevents the use of modern farming machinery. Natural drainage of the soil is another feature of great influence on the use of land. Poorly and imperfectly drained soils occur beside well drained soils on practically all kinds of materials.

Other factors which have influenced the development of soils have been climate, the vegetation growing on the soil, and the length of time the soil has remained in place to be affected by these forces. In a compact area such as Frederick and Carroll Counties, climate may be considered as a fairly uniform influence, although on the mountains the ground remains frozen more of the time than in the valleys. Also, alternate freezing and thawing is more frequent and severe on south slopes than on north slopes, so that physical weathering and erosion have been more rapid on southern slopes. All of the soils of the two counties were developed under forest cover, so that the influence of vegetation has been fairly uniform. The age of the soils varies; over some of the area the material has been in place long enough to allow soil forming processes full expression. Mature soils with distinct and well developed surface and subsoil layers, and considerable depth of partially weathered material, have resulted. At the other extreme are the areas along streams which are still receiving depositions of alluvium and which have not had time to develop any of the soil characteristics other than those of the parent material.

All of the physical features of the soil in some way influence its agricultural usefulness. As soil investigations have progressed, there has been a tendency toward a more and more detailed study of the soil as a natural body. But as knowledge of the soil has been gained, there has been increased realization of its significance in relation to land use; so emphasis has been shifting from recognition of the soil as merely a physical feature of the landscape to its evaluation in relation to other elements in agriculture. This has been speeded up by the economic difficulties which agriculture has experienced in the past twenty years. Out of this has come a widespread recognition that the soil is a natural resource which can be wasted or conserved, and that once it is lost it is very difficult to replace.

Soil Surveys of Carroll and Frederick Counties

The first soil surveys of Frederick and Carroll Counties were made in the summer of 1919 by field men of the United States Department of Agriculture Bureau of Soils and the Maryland Agricultural Experiment Station in cooperation with the Maryland Geological Survey. The work was done using the topographic map which had previously been completed as a base on which soil types were shown. These soil maps, on a scale of slightly over one inch to the mile, give a good general picture of the distribution of soils in the counties as they were classified at that time. Separate county reports were published in 1922 by the Bureau of Soils. The one for Frederick County was prepared by W. J. Latimer and R. T. Avon Burke of the Bureau of Soils, and O. C. Bruce of the Maryland Agricultural Experiment Station. The report for Carroll County was by R. T. Avon Burke. Both reports have been used as references in the preparation of this chapter. County soil maps based on this survey are available from the Department of Geology, Mines and Water Resources.

When soil conservation work was started as a demonstration on a few farms in 1937, it was necessary to have individual farm maps on a larger scale. Soil type, slope, erosion conditions, and land use at the time of the survey were shown on these maps in sufficient detail to serve as a guide in the planning of all soil and moisture conservation measures, field by field.

Later, in May 1939 the Catoctin Soil Conservation District was organized by the farmers of the Middletown Valley. This local organization, through its directors, obtained the cooperation of several State and Federal agencies in carrying on its program of better land use and soil conservation. As part of the assistance from the Soil Conservation Service, a soil, slope, erosion and land use survey was started in July 1939 and completed in April 1941. Meanwhile, farmers in the remainder of Frederick County, and the portion of Carroll County drained by the Monocacy River, had organized the Monocacy Soil Conservation District in October 1939. A similar survey was started for this district in May 1940 and completed in July 1944.

During 1944, farmers in the remainder of Carroll County, with the assistance of the State Soil Conservation Committee, organized the Carroll County Soil Conservation District, and the part of the Monocacy District in Carroll County was transferred to the new district, so that it comprises the entire county. At the same time, the remainder of the Monocacy District was renamed the Frederick District. A detailed survey has been started for the portion of the Carroll District not previously mapped on the large scale.

In all of these surveys in soil conservation districts, the primary object has been to provide a detailed and accurate map of individual farms as an aid in planning soil and moisture conservation programs. The mapping is on aerial photographs. The scale of the maps used for the Catoctin District is approximately eight inches to the mile. The Monocacy and Carroll maps are on a scale of four inches to the mile. Maps of individual farms are copied photographically for the districts and no provision has been made for publication. In general, the soil classification follows that used in the previous survey, with some new separations. There is greatly increased detail in mapping and concern for accurate representation of small areas, because of the emphasis on individual farms and fields. The inclusion of slope and erosion as separate physical factors in the mapping also increases the detail.

LAND USE CAPABILITY CLASSIFICATION

The complexity of the soil pattern in these counties and the large number of soil types make some grouping very helpful in using the surveys. Two groupings have been made for different purposes. The first grouping is a very broad classification of the ability of the land to sustain continued agricultural use. It is called a land use capability classification and deals with the adaptation of the land to various uses—as cropland, pasture or woodland—and the difficulty of maintaining the chosen use. In this classification, slope or the damage already done to the land by erosion sometimes outweighs such things as mode of formation, soil color, and slight differences in soil depth, texture, or natural fertility. Pronounced differences in soil depth, texture, and fertility, and such features as stoniness and natural drainage, are considered as they affect the choice of land use.

The other grouping is based on the old soil classification and groups the soils on similarity of geologic origin in parent material and degree of development. It puts considerable emphasis on factors influencing fertility. Taken together, the two classifications form a thorough evaluation of the soil as a natural resource.

The land use capability indicates the types of utilization which are practical and something of the cost of using the land, while the soil groups suggest crop adaptations and roughly indicate the returns that may be expected.

The land use capability classification for Frederick and Carroll Counties has the following classes and subclasses:

Land suitable for cultivation:

Class I —Suitable for cultivation with ordinary farm practices. Productive, well-drained flat land.

IIa—Suitable for cultivation with simple soil and moisture conservation practices. Productive, well-drained land with some slope or erosion, or both.

IIb—Suitable for cultivation with simple drainage practices. In some cases erosion control practices are also necessary. Fairly productive, flat or slightly sloping land needing some drainage.

IIIa—Suitable for cultivation with intensive soil and moisture conservation practices. Productive, well-drained land with considerable slope or erosion, or both.

IIIb—Suitable for cultivation with intensive drainage practices. Erosion control also needed in some cases. Flat land difficult to drain, or fairly productive sloping land needing some drainage and erosion control.

IIIc—Suitable for cultivation with intensive fertility and moisture conservation practices. Erosion control practices needed in some cases. Droughty very shallow soil with some slope and erosion.

Land suitable for occasional or limited cultivation:

IV —Too steep, too badly eroded, too wet, or too stony for continuous cultivation, but can be plowed to reseed the hay crop.

Land not suitable for cultivation, but suitable for pasture or woods:

VI —Not suitable for cultivation, but suitable for permanent pasture or woods with simple conservation practices. Land which is steep, badly eroded, subjected to damaging overflow, poorly drained, or too stony for cultivation.

VII —Not suitable for cultivation but suitable for forest or wildlife development with intensive conservation practices. Not ordinarily recommended for pasture. Land which is very steep, very stony, very badly eroded or very wet.[1]

TABLE 1

Distribution of Land Use Capability Classes

Land use capability class	Piedmont upland*	Middletown valley	Triassic upland	Frederick valley	Appalachian mountain area
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
I	0.6	9.3	3.8	17.8	0.7
IIa	18.6	32.0	17.7	55.4	9.8
IIb	6.7	5.5	8.9	11.6	0.7
IIIa	35.5	22.4	33.7	7.8	13.1
IIIb	0.8	0.5	1.3	0.7	1.1
IIIc	5.1	0.3	14.7	0	0.3
IV	4.4	4.3	6.9	4.0	3.5
VI	26.7	18.1	11.1	2.5	47.2
VII	1.6	7.6	1.9	0.2	23.6
Total	100.0	100.0	100.0	100.0	100.0
Area	Acres	Acres	Acres	Acres	Acres
Frederick Co.	142,374	52,590	87,121	47,022	96,980
Carroll Co.	238,850	0	47,517	0	0
Total	381,224	52,590	134,638	47,022	96,980

* Estimate based on survey of Frederick County and 90,253 acres of Piedmont Upland in Carroll County.

The extent of each of these classes has been determined for Frederick County and for the portion of Carroll County which is drained by Monocacy River. Table 1

[1] Class V, Land suitable for pasture or woods with no special conservation measures, and Class VIII, Land not suitable for the economic production of cultivated crops, pasture or woods, have been omitted from the classification for these counties. Any land not suitable for cultivation in this area has defects which keeps it out of Class V. Class VIII, if applied to these counties, would only include quarries, and rock outcrops which are usually too small to show on the maps.

shows the distribution of these classes in the five sections of the two counties outlined in Plate 20A.

The Piedmont Upland includes the southeastern one-third of Frederick County and all but the northwestern one-fifth of Carroll County. In this area, slope is the main factor determining land use capability, and erosion is also important. Imperfect and poor drainage affect the capability of only six per cent of the entire area.

About two-thirds of the entire Piedmont Upland is suitable for tillage; some additional land is suitable for occasional cultivation for the reseeding of close-growing, soil-protecting crops. The remainder is too steep, too stony, or too badly eroded for cultivation.

Throughout the Piedmont Upland, the residual soils range from moderately deep to very shallow. Depth of soil is closely related to slope and to the amount of erosion that has taken place. It is an important factor in the usefulness of the land. Under some conditions of erosion, the shallow soil has a poorer land use capability classification than the deeper soils because less soil remains after erosion losses. Minor areas of soil developed on diabasic rocks are limited in use, because they are generally intractable and difficult to till and are frequently stony. A number of small limestone valleys within this area are somewhat similar to the Frederick Valley. In capability for farming use they stand intermediate between the Frederick Valley and the typical Piedmont Upland. In Wakefield, Priestland and Union Bridge Valleys there is more easily tillable land than on the surrounding hills, but it is not as smooth as land in the main area of limestone soils in the Frederick Valley.

The Middletown Valley has a high proportion of land suitable for cultivation in the ordinary crop rotations of the area. Slope is the main factor in determining the type of use and the ease of handling the land. Drainage is a problem on some bottomland soils and some colluvial areas on lower slopes. They would be excellent cropland if they were not limited by a high watertable. Shallowness of the soil is also a limiting factor which is directly related to steepness of slope and the severity of erosion.

The belt of red soils conveniently referred to as the Triassic Upland extends across Frederick County and includes the northwestern corner of Carroll County.

Most of the Triassic Upland soils are residual from underlying red shales and sandstones. Here slope, poor natural drainage, and shallowness are important factors in the use of the land. Where streams have cut well below the general level of the land, the slopes are frequently steep but short. The soil is highly erodible and on these steep slopes is shallow and droughty. About one-fifth of the entire area is too steep, too badly eroded or too shallow for efficient tillage. Much of it is too shallow and droughty for the development of good pastures or high yielding forests. In the areas back from the streams there is gently sloping land that is imperfectly or poorly drained. Large areas have low ridges, which are well drained. They are bordered by imperfectly drained soils on slopes, and there are poorly drained soils in depressions where stream channels have not yet developed. Most of the imperfectly drained soils have a slight hardpan which interferes with root growth as well as water movement. Thus, there is a situation where the land is too wet for cultivation or the best growth of many crops during part of the year, and then dries out and becomes droughty because the plant roots cannot penetrate to the lower subsoil where water is still stored. About one-sixth of the entire area is limited in crop use by lack of adequate drainage. Artificial drainage will improve some of this land.

The soils on the intrusive rocks in the vicinity of Emmitsburg are generally intractable and frequently stony and poorly drained, so that agricultural use is severely limited.

On the western edge of the Triassic Upland there is a strip one to three miles wide, along the foot of Catoctin Mountain, where much of the soil is derived from alluvial or colluvial debris from the mountains, rather than from the underlying rocks. Stoniness and poor drainage cause some of this land to be put in Class VI; some with imperfect drainage is in Class II.

Along much of the eastern edges of the Triassic Upland is a border of soil derived from a calcareous conglomerate, which is sufficiently high in lime to give soil properties similar to those of true limestone soils. This is a fitting transition to the limestone soils of the Frederick Valley. It has a higher proportion of land classes I and II than the remainder of the Triassic area.

The Frederick Valley has a very high proportion of Class I and II land. About 94 per cent of the land is suitable for cultivation with cleantilled crops in rotation. Half of the remainder is suitable for long-term hay. The high productivity of most of the soils, along with favorable conditions for cultivation, has led to intensive use of the land. More attention to soil conserving practices on the gently to moderately sloping areas in Classes II and III is needed to protect this valuable land.

In the Appalachian Mountain area nearly two-thirds of the land is too steep or too stony for use as cropland. Three-fifths of the land classified as suitable for cultivation is steep enough or so badly eroded as to present difficulties in the use of modern tillage equipment and practices. Except for a few valleys and areas along the edge of the mountains, the farmland is scattered in small patches which discourage large scale farming. The Harbaugh Valley is an exception to the general description of the area and closely resembles the Catoctin Valley.

SOIL GROUPING

The classification of soils from the standpoint of origin and mode of formation considers a different set of factors than the land use capability classification. The more detailed information supplements the land use capability study of an area. The factors considered in the soil grouping include parent material, mode of formation, depth of soil, natural drainage, presence of unweathered rock within and on the soil, and the texture or size of the individual particles of soil. These factors, as well as other features, such as color, structure, permeability, compactness, and various chemical properties, may also be used in describing mapping units. Each unit includes a limited range in the factors mentioned above.

For convenience in description, the mapping units may be grouped to some degree, if similarity in features which affect use is maintained. In such a grouping some features outweigh others. Thus stoniness has such a strong effect on land use that stony soils are always kept distinct from non-stony soils which are similar in all other features.

The parent rock materials which are considered as distinct for this survey are as follows:

Sandstones—older than Triassic age
Sandstones—Triassic age
Shales—older than Triassic age
Red shales—Triassic age
Limestone—includes marbles and interbedded schists
Quartzite
Acid schists, phyllites, and interbedded gneisses
Diabase

In their application to soil classification, rocks of widely different age and varying mineral composition are grouped together, if the resulting soils are closely similar in physical appearance. Mode or origin of the soil is considered.

Soils weathered in place from local rock material are classed as residual, and all others as transported. The transported soils in this area are subdivided as colluvial, terrace, and floodplain. The colluvial areas are mostly colluvial-alluvial deposits consisting of gravel, cobbles, and boulders mixed with fine earth. The surface usually has a gentle slope, although close to the foot of the mountains there are fairly steep deposits.

The term terrace, as applied in this area, refers to old alluvial deposits occurring on flats above the highwater floods of present streams. The material has been in place long enough for soil forming processes to have strongly influenced the soil and greatly modified the differences in the original deposits.

The floodplain soils are recent alluvial deposits which are at least occasionally overflowed. The material is so new in its present location that normal soil forming processes have scarcely affected it, and the nature of the deposited material has the greatest influence on the soil characteristics.

The transported soils all have a considerable depth of unconsolidated material over bedrock. If well drained, they have sufficient depth for normal development of deep rooted plants. The residual soils vary from deep to very shallow. In mapping this area, three significant depths have been recognized. The soils described as deep are about three feet thick over rock with a minimum depth of 30 inches. The moderately deep soils are from 14 inches to 30 inches. The shallow soils are generally less than 14 inches deep, but include local areas that are deeper. Although shallow soils are frequently rich in mineral plant nutrients, they lack the water storing capacity needed for the best plant growth during the dry periods which occur most years. Depth of soil is closely related to slope. In the Middletown Valley, three-fifths of the deep residual soils are on slopes of less than eight per cent, and less than one per cent are on slopes of more than twenty-five per cent. On the other hand, over two-fifths of the shallow soils are on slopes greater than twenty-five per cent.

The size of the soil particles is an important characteristic which is closely related to many other soil properties. Chemical reactions in the soil nearly all take place at the surface of the fine clay particles. The coarser particles of silt and sand have such small surface exposed in proportion to their bulk that they are ineffective as a source of plant nutrients or for storage of soluble fertilizer materials added to the soil. The coarser material, however, improves the physical properties of the soil. Loams, silt loams, and fine sandy loams have a blending of fine and coarse particles without a preponderance of any one size. These texture classes are the best for most agricultural uses. Smaller particles may be clustered together as aggregates, which act much as large grains in the physical structure of the soil, but retain the desirable features of fine particles. Thus, some clay soils with good structure have high agricultural usefulness.

In an area such as this, where most of the soils are comparatively shallow over bedrock, and the soil forming processes are active, there are many fragments of rock larger than the eventual soil particles remaining in the upper layers of the soil.

If these rock fragments are large enough and numerous enough to interfere with tillage, the soil is described as stony. A soil with numerous round fragments three to six inches in diameter is described as cobbly. The cobbly soils in this area are on the colluvial slopes at the base of the mountains.

Smaller water-rounded fragments an inch or two in diameter, if numerous enough in the soil, cause it to be described as gravelly. The same term is used for soils having a large quantity of rounded or subangular milky quartz fragments.

Soils with many fragments of sandstone, quartzite, gneiss, or hard schist which are angular and have average dimensions of about 3 x 2 x 1 inches are described as channery. Soils classed as gravelly and channery can ordinarily be cultivated without too great difficulty, although the operation of some farm implements is affected. Numerous small fragments of partly weathered shale or schist cause a soil to be described as shaly. Gravel, shale, or the rock fragments in channery soils sometimes become concentrated at the surface as the result of erosion. When this happens they serve as a mulch, reducing the rate of further erosion.

The natural drainage of the soil is an important factor in its use and consequently in its classification.

A well drained soil is one through which water passes readily and from which excess water is lost before it has time to damage crops. In such a soil a good balance between water and air in the soil pores is restored very soon after a rain has ceased. Compact impermeable layers within the soil, or impervious material beneath it, retard this movement of water and cause temporary waterlogging, which is one kind of imperfect drainage. This condition is shown by mottled colors of the subsoil and by the wetness of the surface soil persisting longer after rains than in well drained soils. Imperfect drainage may also be caused by a fairly permanent water table two or three feet below the surface, as on many floodplains of the smaller streams, or by seep from higher land through the subsoil.

A permanently high water table or seep which keeps the soil saturated most of the time results in poor drainage. A poorly drained soil is recognized by the gray or dark gray color of the surface soil. Most crops do not thrive on such soils.

Swamp vegetation which grows naturally on the soils is very distinct from that of better drained land. In these counties, most of the poorly drained land is distributed in small flat areas at the heads of streams. No stream channel has developed to lower the water table and drainage is over the surface or by very slow seep into underlying rock. Even where artificial drainage by open ditch or tile drain has been introduced, the characteristic gray colors of poorly drained soil persist.

Imperfect and poor drainage in some of the soils is associated with the development of a weak hardpan. It slows the movement of water and interferes with root growth, but is not completely impervious.

A group of soil units similar in all these features except texture and stoniness is known as a soil series. Somewhat broader soil groups will be described separately for each of the five areas shown on the outline map, together with an introductory discussion of the agriculture of each area.

SOILS OF THE PIEDMONT UPLAND

The Piedmont Upland includes 238,850 acres of Carroll County and 142,374 acres of Frederick County, or 54 per cent of the total area of the two counties. As nearly as can be estimated from 1940 census data, 336,339 acres of this total of 381,224 acres is in farms. There is some variation in agriculture, and there is a higher proportion in farms in Carroll County than in Frederick. Also, the average farm in the Frederick County section is larger and has more cropland. Land values and crop yields, however, average lower. Slightly over one-fourth of the total crop area is corn; another fourth is wheat. The remaining cropland area is hay and a number of minor crops, including barley, oats, and vegetable crops raised for canning. In 1939 Carroll County had ten thousand acres of cannery crops, mostly sweet corn, peas and tomatoes. This production is spread over both the Piedmont and the Triassic sections of the county. Frederick County had smaller acreages of these crops. An increased acreage of canning crops is being grown in both counties during the war.

Canning crop production calls for intensive use of the land, with the early crop of peas being followed by some other crop. Except when the following crop is a new seeding of alfalfa, this practice is especially hard on the soil.

In the 1919 Soil Surveys of these two counties, five-sixths of the Piedmont Upland were included in the various types and phases of two soil series, the Chester and Manor. In the recent more detailed surveys, a number of additional series have been recognized. This has been done partly by limiting the definitions, so that a smaller range of conditions is included in one series, and partly by more detailed mapping, permitting the separation of soils which occur in small scattered areas. Plate 20B illustrates the complex pattern of the soils and slopes as mapped on a detailed conservation survey at a scale of four inches equal one mile. Mapped on a scale of one inch equals one mile, this area had to be generalized and was shown as nearly all Manor loam. For comparison, Plate 21A shows the land use capabilities of the same area. On the more detailed survey, much of the Chester was found to be shallower than the typical Chester profile; also the Manor included areas deeper than typical, particularly in the Manor loam type. The intermediate depth of soil, therefore, was included in the Glenelg series, which had been established since the original surveys. Small areas of imperfectly drained soils, especially along the lower slopes adjacent to stream floodplains, were separated as the Glenville series. Soils derived from dark-colored slates formerly included with the Manor slate loam, but mentioned in the description as a variation, were separated as the Linganore series.

Minor soils in the area include Cardiff slate loam, associated with and developed from the Antietam quartzite, and related to it a poorly drained soil, the Orange silt loam. The areas of Conowingo soil in Frederick County were re-examined in comparison with other Conowingo soils and given a local name, Urbana. The Hagerstown soil mapped in the Piedmont Upland is in association with the Wakefield marble and the Silver Run Limestone. In detailed mapping it has been possible to separate several series, including Strasburg, Conestoga and Emory, in addition to Hagerstown, in this area. Soils on Sugarloaf Mountain are nonagricultural stony loams and Rough Stony Land, and are similar to those of the Mountain area in the western part of Frederick County.

WELL DRAINED SOILS

Deep, well drained residual soils are the best upland soils in the area. The Chester[2] series developed on acid schists, gneisses, phyllites and metabasalts is the most extensive of the group. It is easily tilled and provides a good medium for plant roots. The natural fertility is moderately high, and crops on it respond well to lime fertilizer and manure. The Elioak series resembles the Chester, but has a reddish-brown subsoil somewhat heavier than that of the Chester. It is not extensive. The Hagerstown*, Conestoga, and Strasburg of the small limestone valleys are higher in native fertility, but the last two are especially susceptible to erosion. The subsoil of the Conestoga is exceptionally friable, because of a high proportion of talcose material, and is therefore subject to severe gully erosion when not specially protected. In the southeastern part of Frederick County, there are small areas of Nason silt loam, a soil of only moderate productivity derived from quartzite.

The Montalto* soils occur on a few ridges in this area, where diabase is exposed. They are rich in natural fertility, but a high proportion of the series is stony and in places the surface soil is heavy. The subsoil is tight and intractable. It is not very desirable, therefore, for clean tilled crops, but is good for pasture, and the nonstony types are very good for orchard and hay land.

The Urbana (Conowingo*) series, except the shallow phase, may be included with these deep soils, although the natural drainage is not quite as good as in the others. This soil, which occurs in a belt through eastern Frederick County in the vicinity of Urbana, New Market and Oldfield, is derived in part from serpentine. The surface soil is dark brown and granular; the subsoil is dull yellowish-brown, somewhat plastic clay or clay loam. When dry, the subsoil is hard and intractable. Most of the series occurs on moderate slopes. Surface drainage is good and erosion is frequently serious. However, the tight subsoil and dense underlying rock keep internal drainage and aeration from being as good as in other deep soils described in this group. Because of the unfavorable physical structure of this soil, yields are usually lower than on Chester.

The Glenelg series includes most of the soils of moderate depth in this area. Like

[2] An asterisk used with a soil name indicates that it is used in the Carroll or Frederick County soil survey reports, 1922, and occurs on the soil maps, scale one inch equals one mile.

the Chester, it is residual from schist, gneiss, phyllites and metabasalt. The total thickness of the soil over partially weathered but still recognizable bedrock seldom exceeds thirty inches and is, usually, much less. There is definite subsoil, but it is less pronounced than in the associated Chester soils. There are more fragments of partially weathered rock in the surface soil and subsoil than is the case with the Chester. Although it occurs on a wide range of slopes, the greatest distribution of Glenelg is on moderately sloping land somewhat steeper than the Chester. Much of it is in land use capability class III, with lesser areas in classes II and IV. Agricultural use is about the same as for Chester, but more conservation practices are needed to protect the soil. In average seasons, yields will be lower than on Chester, because of the smaller reserve of soil moisture.

Along the western edge of the Piedmont Upland, there are several areas of moderately deep soils which are inferior to the Glenelg for various reasons related to the parent material from which they have developed. The Cardiff* soils on the Antietam quartzite, which in this area is a quartzose schist, are low in plant nutrients and usually occur on rolling to steep areas. The Edgemont soil is associated with outcrops of quartzite, which are coarser in texture than the local phase of Antietam quartzite. The soil is gritty and very low in plant food. Much of it is stony. It ranges from deep to shallow, but is typically moderately deep.

The Manor* series is the typical shallow soil of the entire Piedmont Upland. It is characteristically developed from schists, but may come partly from gneiss, phyllite, and metabasalt. In places, the parent schist is highly micaceous. The soil is rarely more than 20 inches deep, and much of it is only 10 or 12 inches to partly weathered parent material. However, weathering processes have attacked the rock to considerable depth, and hard rock is seldom encountered for several feet below the surface. Soil development has been slight. Usually, there has been a little subsoil developed, but it is only slightly heavier than the surface soil and is often merely a transition from the surface to the parent material, rather than a truly developed subsoil. The Manor types as mapped include much land which originally had a Glenelg profile, but which has lost so much of its surface by erosion that it is now equivalent to Manor in depth and moisture-holding capacity. The present surface soil of this is a mixture of the old surface soil, subsoil, and parent material. The Manor commonly occurs on the steeper slopes adjacent to areas of Chester and Glenelg, but it also includes some gently sloping areas where soil development has been slight. The parent material is usually rich in plant nutrient elements, and these have been only partly leached from the soil so that the fertility level is high. The extreme shallowness of the soil reduces its capacity for retaining water, and also for supplying available plant food, so that it is not a highly productive soil in average seasons. Crops are good in years when rainfall is well distributed throughout the entire growing season and on land that has been carefully managed to maintain the organic matter in the surface soil and to build up the supply of available nutrients. Some of it is in land use capability class III and is farmed much as the deeper soils. A relatively small area is in class II. More is in higher classes which are not suitable for tillage. Productivity of pastures and some haylands is limited by the droughtiness of the soil.

The stony type of this soil is not very extensive, but occurs in many scattered areas, mostly on the steeper slopes.

Shallow soil over black or bluish-gray slates was included with the Manor slate loam in the soil survey of Frederick County published in 1922. On the more detailed survey of the Monocacy Soil Conservation District, this soil was given the name Linganore. Most of it occurs in the Linganore Hills of eastern Frederick County. The soil has a gray or brownish-gray surface and light gray subsoil. Subsoil development is usually slight. This soil occurs on rolling to steep land, and on much of it ridges of bedrock come to the surface or can be reached by the plow. It is a poorer soil than the Manor, where it occurs in large areas. Most of it occurs closely mixed with Manor, and even when mapped on a scale of four inches equal one mile, many streaks of Manor are included with the Linganore. Agricultural use is about the same as on the Manor, except that it is slightly less intensive.

There are a few gneiss ridges in eastern Frederick County, where the soil is shallow and droughty, which are mapped as Brandywine series. Large fragments of the parent rock occur throughout the soil, and it seems more sandy than other soils in the area. There is little or no subsoil development, and the soil is excessively permeable to water, but retains very little for plants to use. Most of the series is in woods, or is idle. On some of the igneous dikes there is a shallow soil to which the name Legore has been given. It shares some of the characteristics of Montalto, but is not nearly as good a soil. The shallow phase of Urbana, which is associated with the typical Urbana, is difficult to till, but much of it is farmed along with better soils adjacent to it.

Along some of the larger streams, there are old alluvial deposits which are no longer overflowed by the stream. The soil material is derived from the upland soils of this area. The well-drained terrace soil, named Wickham, has a profile similar to Chester, except that it is deeper to bedrock and the subsoil is not so well developed. In agricultural use and productivity, it is similar to Chester. Most of it is level and is included in land use capability class I. There is very little of this soil in the area.

On the floodplains of the present streams there is no soil development, beyond the accumulation of some organic matter in the immediate surface soil.

The only well drained floodplain soil in this area is the Congaree* series. As mapped in the 1919 survey, it included soils in which the watertable was high enough to restrict the roots of many plants to the surface soil. As now mapped it includes only the soils that are permeable and at least three feet deep to the watertable, except during freshets. The soil is highly fertile and crop yields are high, except when crops are damaged by floods. The degree of flood hazard varies from place to place, but generally the returns from cropping it balance the risk.

IMPERFECTLY DRAINED SOILS

Imperfectly drained soils, where natural drainage and aeration are impeded either by a slowly permeable soil horizon or by a high water table during part of the year, are not extensive in this area, but present special problems. Frequently small areas occur in fields of well drained soils where they interfere with normal tillage operations, especially in the early spring. Some crops do not thrive on them, but summer annual crops frequently do very well because of stored water in the lower subsoil. Artificial drainage may be used to improve the soil, particularly where small areas need to be drained. On large fields of these soils, care in the selection of crops to be grown may be the only special practice needed.

The most extensive imperfectly drained soil in the area is the Glenville series. On the original survey, it was not separated from the Chester and Manor, but is now recognized as occurring on gentle slopes and in basins around stream heads throughout the Piedmont Uplands. Most of it is on lower slopes where colluvial accumulation has taken place. The surface soil is nearly always a grayish-brown silt loam. The subsoil is heavier in texture and moderately compact. It is usually a pale yellow color with faint mottling of gray and rust brown. Mottling becomes stronger with depth. The soil is relatively fertile, but the imperfect drainage constitutes some limitation on its use. Slopes are slight, making tillage easy. Where run-off is received from higher land, there is considerable erosion loss, including some gullying. When this soil is protected by grass and higher land is eroding, it often accumulates soil washed down and deposited. The Orange series associated with the Cardiff is similar to the Glenville, except that the subsoil is more compact and it is lower in fertility. Included in the Orange are some small spots which are poorly drained. On the old alluvial terraces there is a soil, the Altavista, which closely resembles Glennville. It is practically all level and is very desirable cropland, except for deep rooted perenniel crops such as alfalfa.

On the stream floodplains, the Codorus series includes those soils which have an intermittently high water table, as shown by gray and rust-brown mottling at depths from 15 to 36 inches below the surface. The land is occasionally overflowed, with some resultant damage to crops. Corn and hay crops, however, do well on it, and about one-fifth of it is cultivated. Nearly two-thirds is used for pasture, as it furnishes summer feed when pastures on hill lands are not producing very much. This is the most extensive soil on the floodplains and is an important element in the organization of most of the farms in the Piedmont Upland.

POORLY DRAINED SOILS

Poorly drained soils in this area are small in extent, but important because of their sharp contrast with surrounding land. They present serious obstacles to cultivation and when cropped along with other land they often show complete crop failures. The Worsham series occupies flat areas at stream heads and adjacent to small streams in the upland. It has gray surface soil and mottled gray-yellow and rust-brown heavy subsoil. It is of little agricultural use, except as poor pasture land or as woodland, unless artificially drained. The Lantz series is similar to the Worsham, except that the surface soil is black because of the accumulation of organic matter. The Roanoke series on alluvial terraces also resembles the Worsham. On the stream floodplains, the Wehadkee* series is saturated to within a few inches of the surface most of the time. During wet seasons and after floods, water frequently stands on the surface. The area of Wehadkee along some streams has been increased by clogging of the channels which raised the water table in soils that were formerly better drained. When flooded in this way, the soil quickly takes on many of the physical characteristics of a poorly drained soil, although the reverse process, in soils where drainage has been improved, is relatively slow. With a moderate amount of artificial drainage, much of the Wehadkee can be made into good pasture land or woodland.

SOILS OF THE MIDDLETOWN VALLEY

The Middletown Valley as shown on Plate 20A is about 7.4 per cent of the entire area of the two counties. This area closely agrees with the area included on the 1919 soil map of Frederick County as three soil types—Ashe loam, Ashe silt loam, and Porters silt loam—and associated floodplain soils. In the more detailed survey of the Catoctin Soil Conservation District, there is a total area of 52,590 acres of the valley soils. The watershed of Catoctin Creek includes about 30,000 acres of mountain land in addition to this valley. Agriculture is mostly concentrated on the valley soils at elevations between 350 and 800 feet above sea level. Census data for minor civil divisions that are mostly within the Middletown Valley include the adjacent mountains and some land outside of the watershed, so that they do not reflect the intensity of agriculture on the good valley soils. At the time of the conservation survey, it was found that 82 per cent of the area of six of the best and most extensive soils in the Valley was cropland and only one per cent was idle. Cropping practices are very similar to those in the Piedmont Upland. Over one-fourth of the cropland was used for corn in 1939 and nearly one-third for wheat. Plowable pasture per farm is somewhat higher than in the Piedmont Upland. Most permanent pasture is on floodplain soils. Crop aftermath and the second year of hay on rotated cropland are used for pasture on many farms. The intensive use of the land is shown in Plate 21B, which also illustrates the rolling to hilly topography of the Valley, as well as suitable soil and water conservation practices.

WELL DRAINED SOILS

In the 1919 survey, all of the residual soils in the Valley were included in the Ashe* and Porters* series. These have been redefined and limited to mountain soils in the Blue Ridge, so that the names now used for the soils of this area are recent introductions.

In the areas shown as Ashe* on the Frederick County Soil Survey, the principal deep, well drained residual soil is the Myersville series. This soil is developed from various schists. The surface soil is a light brown silt loam, and the subsoil is a yellowish-brown silty clay loam. The soil is friable throughout the entire profile and is permeable to plant roots and water. The natural fertility level is fairly high and the agricultural adaptation is wide. Three-fourths of the total area of about 30,000 acres of this soil is on moderate slopes of less than 15 per cent. That the soil mantle is fairly uniform is shown by the presence of less than 500 acres of the stony type. For the non-stony types, over four-fifths is used as cropland. Most of it is in land use capability classes II and III.

The Fauquier soils are similar to the Myersville except that the surface soil is darker brown and more granular and the subsoil is reddish-brown and slightly heavier and more compact. It occurs on slightly smoother land than the Myersville, over half being on slopes of less than eight per cent. Agricultural use is the same as for the Myersville.

Shallow to moderately deep soils in this area are included in the Catoctin series and in the shallow phase of Fauquier which total just over 3,000 acres. They resemble the soils just described, except that less subsoil is developed and partially weathered bedrock is reached within 10 to 24 inches of the surface. They are distributed in small areas on steep slopes throughout the valley. Less than one-eighth of the total area is on slopes of less than 15 per cent. About three-fifths of the total area is used for cropland.

On gentle lower slopes there has been a deep accumulation of colluvial material derived from the local uplands. The well drained soil on this material has been named Meadowville. It has a brown silt loam surface over reddish-brown or yellowish-brown silt loam subsoil. Land use is about the same as on the residual soils. Over nine-tenths is on slopes of less than eight per cent. Erosion is generally slight, and more land has received recent deposition than has suffered serious erosion.

Along the larger creeks and near the Potomac River there are high alluvial terraces which are not flooded. On well drained locations along the creeks there is a total area of 167 acres of Wickham gravelly loam which is similar to the Wickham of the Piedmont Upland area. Near the Potomac River there is a small area of terrace derived from old alluvium, which is mostly sandstone and shale material. It is thoroughly leached and much lower in fertility than the Wickham. It is classified in the Waynesboro series.

On the floodplains of the local streams the well drained soil is included in the Congaree* series. Over half is used for cropland despite occasional overflow, and over one-third is used for pasture. Along the Potomac River, where alluvial material is derived from widely scattered sources including limestone valleys and sandstone mountains, the floodplain soils are classed as Huntington*. Textures range from medium to light. In this area four-fifths of the Huntington is forested, which is in contrast to its typical intensive use as cropland and pasture. This is partly because the area is cut up by railroad and canal rights-of-way, and because it includes some very low, frequently flooded land. Much better Huntington soils are found in the Frederick Valley area.

IMPERFECTLY DRAINED SOILS

On the colluvial slopes associated with the Meadowville and the various upland soils, there is a considerable area of imperfectly drained soil included in the Glenville series which has already been described for the Piedmont Uplands. In this area about half is used for cropland, and one-third for pasture.

The Codorus silt loam is the imperfectly drained floodplain soil of this area. A seasonally high water table somewhat limits its usefulness, but it provides good summer grazing and over two-thirds is used for pasture. About one-fifth is used for crops.

POORLY DRAINED SOILS

A comparatively small part of the floodplain is poorly drained and is included in the Wehadkee series. Over one-half is used for pasture and one-fourth is cropland, although it is not very desirable for either use without some artificial drainage.

Both Codorus and Wehadkee are flat and subject to flooding which sometimes damages crops.

SOILS OF THE TRIASSIC UPLAND

The Triassic Basin occupies a wedge-shaped area in Carroll and Frederick Counties with the point at the Potomac River below Point of Rocks and the base extending along the Pennsylvania boundary from west of Emmitsburg to a point six miles northeast of Taneytown. The Triassic soil area is interrupted by an area of limestone and colluvial soils just west of Frederick.

Triassic material fills valley indentations along the border of the Piedmont Upland. There is an isolated area in a small valley near Tyrone, where Triassic material has been preserved by downward faulting. Just east of the mouth of Monocacy River there is an edge of another Triassic Basin which is extensive in Montgomery County. The total area is 134,638 acres of soils from definitely Triassic material. Included in the area outlined on Plate 20A are some colluvial material of outside origin and some limestone soils. The Triassic area is about 19.0 per cent of the total for the two counties. The average area of cropland per farm is somewhat higher than in the Piedmont Upland section, but not as high as in the Middletown Valley. Pasture land per farm is also fairly high, with an average of 16.6 acres. The area of woodland in farms is low, slightly over half as much as in the Piedmont Upland. This may reflect the prevailingly moderate slopes, as contrasted with the scattered areas of steep slopes in the more hilly Piedmont. Plate 22A shows soil, slope, erosion and land use for a typical area in the Triassic Basin. Plate 22B shows the land use capabilities of the same area. Values of land and buildings are about the same per acre as in the other areas already described. Corn and wheat acreages per farm are close to the two county average, but yields per acre are slightly below the average. Each of these crops occupies over one-fourth of the cropland.

The most striking feature of nearly all the soils of the Triassic Upland is the reddish-brown color inherited from the predominantly red shale, sandstone and conglomerate rocks. Lighter colored soils are associated with local areas of gray sandstone. Also some of the best developed residual soils have lost most of the red color from the surface soil by weathering processes. The red color of the imperfectly drained soils has been faded or destroyed by reduction of the red pigments to gray and blue, due to the frequent waterlogged condition of the subsoil. In the poorly drained soils, the red color has been almost entirely removed or obscured by accumulated organic matter.

WELL DRAINED SOILS

The deep, well drained residual soil associated with the red shale is not extensive, but it is very desirable land because of its good physical properties. This soil is now classed as Bucks silt loam. In the 1919 soil survey it was included with the Penn silt loam*. It occurs on gently sloping ridgetops associated with the Penn soils. The surface soil is grayish to yellowish-brown silt loam eight or ten inches deep. Beneath this there is reddish-brown granular silty clay loam which becomes more compact with depth. Bedrock is usually at a depth of about 40 inches. It is good farm land, with most of the areas in land use capability classes I and II.

East of Thurmont there is a considerable area in which the soil material is much deeper over bedrock than in the rest of the Triassic Upland. The soil material and the entire soil profile is reddish-brown in color and is characterized by partially rounded gravel or cobbles. The subsoil is compact and the parent material is very compact. On the Frederick County soil survey map this area is shown with the Penn silt loam* but with gravel symbols added. On resurvey it is included with the Norton gravelly loam, which is a glaciated soil having all these characteristics. It occurs on gentle to moderate slopes and is highly susceptible to erosion. Most of it is in land use capability classes II and III. Some stony areas of this series are in classes VI and VII.

Associated with the limestone conglomerate at the base of the Triassic formation are areas of the Athol* series of soils. These soils share the characteristics derived from limestone and shale. The surface soil is dusky red or brown gravelly loam with coarse granular structure. The upper subsoil is moderate reddish-brown clay loam, which is fairly compact with nutlike structure. The lower subsoil is weak reddish-brown clay loam or clay, which is very compact, somewhat plastic, and has blocky structure. Both internal and external drainage are good. The soil occurs on moderate slopes and erosion is active although not as severe as on most of the Triassic soils. Productivity is high and nearly all of the Athol soils are cultivated, except for stony areas near Point of Rocks. The Athol gravelly loam, yellow subsoil phase,* differs from the typical soil in color and by having slightly impeded drainage. Typically, the yellow subsoil phase is on lower and flatter areas than the other. Both phases have a high proportion of land use capability classes I and II.

The Montalto series occurs on igneous sills and dikes, particularly in the area north of Emmitsburg. Here it is in larger areas than in the Piedmont Upland. Much of it is stony. In the less stony areas, cultivation is possible, but is somewhat restricted by the heavy texture and plastic consistency of the subsoil and much of the surface soil. Slopes are moderate and, where the soil is clean tilled, erosion is active. It is an excellent grass soil and very good for orchards.

By far the most extensive soils of the Triassic Upland are the well drained soils of intermediate depth. The Penn* series derived from the red shales and sandstones and the Lansdale* series associated with gray sandstones account for nearly all of the well drained area. In places the differently colored materials are so closely interbedded that they cannot be separated in mapping. The Penn silt loam, mixed phase,* of the Carroll County soil survey, and the Penn-Lansdale loam of the conservation survey, are the mapping units for this condition. In the conservation survey a Penn shale loam has been separated as a very shallow soil to which the description of the typical soil does not apply.

The Penn* soils have reddish-brown surface soil of medium texture and reddish-brown subsoil of only slightly heavier texture, which grades into partially weathered

red shale or sandstone at depths varying from 18 to 30 inches. There are some shale and sandstone fragments throughout the soil profile. The Lansdale series has a light brown loam or sandy loam surface and yellow to yellowish-brown loam subsoil, and is usually about 30 inches deep to sandstone.

Both Penn and Lansdale occur on slopes ranging from level to steep, but they are typically moderately rolling. Erosion is very active and most of the surface soil has been lost from many areas of these series. Land use capability class III is most extensive with considerable areas of class II. Most of the land is used for cropland, with minor areas of pasture and woodland. The Penn series is considered a good orchard soil.

The Penn shale loam is a very shallow soil associated with other types of Penn. It is considered a definitely inferior soil. The surface layer which averages about four inches deep is a reddish-brown shaly silt loam. Underneath this to an average depth of 16 inches is reddish-brown shaly silt loam. The depth to bedrock ranges from less than 10 inches to about 20 inches. The slopes average steeper than for the other types of Penn. Much of this soil occurs on short choppy slopes, where it is difficult to apply conservation farming methods. Some of this type, as it is now mapped, represents areas that were formerly deeper, better types of soil, but have lost much of the normal soil profile by erosion. The soil is droughty because of the low water holding capacity. Strangely enough, because of the shallow profile being underlain by solid shale, this soil frequently becomes waterlogged during periods of excessive rainfall.

The total reserve of plant food is also low, so that the soil must be classed as low in productivity. Some of it is idle or is growing drought-resistant trees or shrubs, but most of it is cropped with indifferent results. Drought-tolerant crops, such as lespedeza, offer some hope for better returns from this land.

The Steinberg series is a similar shallow soil, except that it is mainly derived from gray sandstone and is lighter in texture, and consequently even lower in fertility.

Associated with the Montalto* on the diabasic rocks, are fairly large areas of shallow to moderately deep soils of the Legore series. This series has already been described as it occurs in the Piedmont Upland. In this area much of it is too stony for cultivation.

Along the western edge of the Triassic Upland the colluvial and alluvial soils from Catoctin Mountain extend over the red shales and also over the limestone that occurs in a few spots west of the Triassic rocks. On the Frederick County Soil Survey, this soil on colluvial material was mapped as Allen gravelly loam* if it was over shale, and Murrill gravelly loam* if over limestone. Stricter definition of these soil names in other areas had led to reclassification in this area. The Braddock series has dark reddish-brown surface soil, moderate reddish-brown subsoil, becoming lighter in color with depth. The Thurmont soil is brown. Both are moderately compact in the subsoil, but friable and permeable. Both vary greatly in texture and in stone content. Commonly there is quartzite and sandstone gravel throughout the entire soil profile. In places there are boulders of sufficient size to prevent cultivation, and these areas are classed as stony types. The layer of colluvial material is so deep over the limestone areas that the soil does not show much influence of the limestone. The Braddock is rated as of high productivity, and the Thurmont as having low fertility. Good physical structure and the predominantly gentle slopes favor cultivation. The stony types are not cultivable and the cobbly types are difficult to till satisfactorily.

The well drained deep terrace soils along Monocacy River and other large streams of the area are in the Birdsboro series. Most of the land is in land use capability classes I and II. Floodplains of these streams have fairly large areas of Bermudian silt loam* and fine sandy loam. The Bermudian silt loam* of the 1919 survey included much of the imperfectly drained soil which is mapped separately in the more recent surveys. Much of the Bermudian* is used as pasture and some is cropped. Crop yields are not quite as high as on the Congaree of the Piedmont Upland.

IMPERFECTLY DRAINED SOILS

On broad flats in the Penn area is an imperfectly drained soil which is moderately deep to a tight, almost impervious clay layer which greatly restricts water movement through the soil. This land has been separated as the Readington silt loam. The surface soil is weak reddish-brown granular silt loam. The upper subsoil is pale reddish-brown slightly compact silt loam. Below 18 to 30 inches this becomes mottled with olive-gray. This mottled layer is heavier in texture and is very compact and tough. This soil dries off later in spring than the surrounding well drained soils, and becomes waterlogged during periods of heavy rainfall in summer. There is also danger of heaving during the winter, so that the imperfect drainage constitutes a limitation on land use. Alfalfa and barley are liable to serious damage. Hay crops and in many seasons corn and soybeans thrive on this soil. Because of the slight slopes of most of the land, erosion has not been severe. The impermeable subsoil, however, causes a high rate of run-off when the soil becomes saturated, and serious gullying occurs where the water concentrates. Construction of drainage type terraces improves this soil by removing excess water and reduces the erosion.

Adjacent to igneous dikes where the shale has been metamorphosed, the soil is characteristically imperfectly drained. It is classified in the Lehigh* series. The most extensive areas are between Emmitsburg and the Pennsylvania state line. Most of the land is gently sloping. The erodibility of this soil is high and it has been seriously damaged by both sheet and gully erosion. On the igneous dikes and sills are flat or nearly flat areas of Iredell* soil which are imperfect to poorly drained. The surface soil is brownish-gray silt loam where it has not been eroded. The subsoil is tough plastic clay loam which is mottled dark yellowish-brown and light olive-gray. Agricultural usefulness of this soil is sharply limited by the intractable subsoil and by wetness. Much of the total area is too stony for cultivation.

Associated with the Birdsboro on stream terraces is an imperfectly drained soil, Raritan silt loam. It resembles the Readington of the uplands. The most extensive floodplain soil in this area is the imperfectly drained Rowland silt loam. If undrained it is best adapted to pasture or hay. With artificial drainage it becomes suitable for crops, but is distinctly poorer than Bermudian in most seasons.

POORLY DRAINED SOILS

Around streamheads and on flats associated with the Readington, Penn and Lansdale is a gray surfaced, poorly drained soil which has been given the name Croton. It is shallow to a hardpan which is very slowly permeable to water, so that in wet seasons the soil is waterlogged and in dry seasons the shallow surface soil dries out and plants are unable to reach water which may still be abundant underneath the hardpan. It is a poor agricultural soil, but has some usefulness as pasture and hayland. Most of it is in land use capability class IV. Associated with it are a few small areas of a very poorly drained soil, the Stanton silt loam, which has a darker colored surface and remains saturated nearly all the time. In the area of igneous rocks north of Emmitsburg, is some poorly drained soil classified as Watchung silt loam. It is similar to Croton in drainage, but even more plastic and intractable, so that cultivation is not feasible.

On stream terraces along Monocacy River are some small areas which are poorly drained because of seepage or high water table. These are classified as Lamington silt loam. On stream floodplains in the Triassic area, the land with high water table is classified as Bowmansville silt loam. Both Lamington and Bowmansville are best adapted to use as pasture land. The quality of pasture can be improved by installation of enough surface drainage to permit mowing and to encourage more desirable pasture grasses.

SOILS OF THE FREDERICK VALLEY

The Frederick Valley constitutes only 6.6 per cent of the total area of the two counties, but because of the high quality of most of the soils it has an importance greater than its relative size. Ninety-five per cent of the total area is in farms. The remainder is occupied by towns, including the city of Frederick, and industrial or recreational sites. The farms are larger than in any of the other sections of these two counties. The per acre value of farm land and buildings is 64 per cent above the two-county average. Of the 112 acres in the average farm, about 75 acres is used for cropland, 17 acres for pasture and only 5 acres is woodland. The acreages of corn and wheat per farm exceed those in any other parts of the two counties. Yields of corn, wheat and alfalfa are high. These outstanding agricultural features are largely a result of exceptionally favorable soil conditions. Plate 23A shows the complete use of the land on a few farms in the Frederick Valley.

WELL DRAINED SOILS

Most of the area has well drained deep soils residual from limestone. The Duffield series is the most extensive. In the survey made in 1919 it was included with the Frankstown silt loam*. The surface soil is a pale brown mellow silt loam which in places contains enough gravel to be recognized as a gravelly type. The subsoil is a yellowish-brown silty clay loam which is compact but friable. Below 24 inches the subsoil is mixed with soft yellow shale. The underlying rock is argillaceous limestone. The land is level to gently rolling, and a high proportion of it falls in land use capability classes I and II. Erodibility is moderate. Although erosion has generally not been severe, some erosion control measures are needed under the fairly intensive cropping that is being done. More soil improving crops and careful return of crop residues is needed to maintain the organic matter supply of the soil. The Frankstown* series is similar in color and in origin, but differs in having a lighter textured, less compact subsoil, and in containing more shale fragments throughout the soil. The average depth to rock is less than in the Duffield. It occurs mostly on gently rolling surfaces. Erosion has been more active and special practices are needed for its control. Land use capability classes II and III are most extensive.

The Hagerstown* series is associated with high grade limestone east and southeast of Frederick. It has already been noted as occurring in some of the smaller limestone valleys in the Piedmont Upland area. The surface soil is chocolate-brown friable silt loam. The upper subsoil is a light brown granular silty clay loam. Below 15 inches the subsoil becomes reddish-brown clay or silty clay which is compact and blocky. The Hagerstown sandy loam* differs from this description by having a much lighter texture throughout the entire profile, and therefore having lower waterholding capacity and less natural fertility. Slopes of the Hagerstown vary from level to gently rolling with numerous areas of short steep breaks. Rock outcrops are fairly common and the stony sandy loam is an important type in the area. It is better adapted to pasture or continuous use for hay land than to cultivation, although some of it is tilled over and around the rock ledges. Land use capability classes range from I to VI depending upon slope, erosion and stoniness.

A shallower soil associated with the Duffield has a tight clay loam subsoil which somewhat impedes internal drainage. This soil has been called Edom shaly silt loam. It is not extensive in the area.

Much of the limestone area does not have a complete pattern of surface streams, and natural drainage is through the soil into crevices in the limestone. Very deep soil has accumulated in some of these low places. Where it is associated with the Duffield, this soil has a dark yellowish-brown silt loam surface, and a moderate yellowish-brown silt loam subsoil. It is friable throughout and has excellent water storing capacity, although it is well drained. In the 1919 soil survey it was mapped as Frankstown silt loam, colluvial phase*. It is now classified as the Araby silt loam. A similar soil, the Emory silt loam, is associated with the Hagerstown. It is darker in color with a reddish-brown silty clay loam subsoil. Both occur on nearly level depressions where there is little or no erosion. Both are in land use capability class I and both are excellent cropland.

Along the lower course of Monocacy River and some of the larger tributaries and near the Potomac River, is a well drained terrace soil, the Elk* series which is derived mainly from limestone uplands. The soil is similar to the Emory, but lighter in texture and lower in fertility. It is generally level except for short steep slopes along the edges of the terrace deposits. The Huntington* series includes the well drained bottomlands along streams draining the Limestone Valley. In the 1919 survey the imperfectly drained floodplain soils were included with Huntington*. As now defined, it is a very productive soil where used for crops, and a reliable pasture soil. In some localities it is subject to sufficient flooding to make cropping hazardous, but in general it is considered good for corn and for hay crops.

IMPERFECTLY DRAINED SOILS

There are small areas of imperfectly drained upland soils in the limestone area which are mapped as Colbert silt loam*. The subsoil is very tight and moderately plastic. The land is best suited for pasture.

Associated with the Emory and Araby is an imperfectly drained colluvial soil, the Wiltshire silt loam. The soil and subsoil are friable, but in wet weather drainage is slow enough to cause the soil to remain waterlogged long enough to restrict root growth. The soil is fertile and would be excellent cropland except for the restriction imposed by the slow drainage. On the stream terraces are some small areas of Captina soils which are similar to the Elk series, except for having tight, slowly permeable subsoil which keeps drainage slow.

On the floodplains the Lindside soils provide excellent pasture land. Though drainage is imperfect and the water table is usually within three feet of the surface, considerable areas of Lindside are cropped with good yields of corn and hay. Flooding occasionally damages crops.

POORLY DRAINED SOILS

Poorly drained soils are of very small extent in the Limestone Valley area. They include the Guthrie series in Upland and colluvial positions, the Robertsville on stream terraces, and the Melvin and Dunning on the floodplains. All remain wet for a large proportion of the average season. They are best suited for pasture or woodland. Their value for pasture is increased by artificial drainage. Thorough drainage makes them usable as cropland, and yields may be high because of natural fertility stored in the soil. This is especially true of the Dunning, which is a dark-surfaced soil with high organic matter content.

SOILS OF THE APPALACHIAN MOUNTAIN AREA

The rough mountainous area of the western part of Frederick County has a total of 96,980 acres or about 14 per cent of the two-county total. Only one Magisterial District, Hauvers, is entirely within this area. According to census information for this district, less than 60 per cent is in farms. The average size farm is 71 acres, which is much smaller than in any of the other areas. The acreage of cropland per farm is less than half as large as the average for the two counties and reflects the difficulties of cultivating the steep land with stony or shallow soil. The acreage of plowable pasture is also very low. Corn averages about six acres per farm and wheat about three, whereas 13.7 of corn and 14.0 of wheat is the average in the two counties. Area of woodland per farm is more than double that in any other section of the two counties. Value of farm land and buildings per acre and per farm are the lowest for any area. The non-farm land is nearly all forested.

The land surface is steep and rugged. A large proportion of the residual soils are shallow and about six-tenths of the entire area is stony, including a high proportion of Rough Stony Land. The mountain soils are developed on a variety of quartzites, sandstones, and schists. Along with the truly mountain soils are some areas in small valleys with soils similar to those of the Middletown Valley. Plate 23B shows a sample of the soil and land use pattern in such an area with small fields on the smoother, better soil and a large proportion of woodland.

WELL DRAINED SOILS

Of the well drained upland soils, the Clymer series is the deepest. It occurs on a few sandstone and quartzite ridgetops. It is not extensive and is not being farmed in this area. Myersville and Fauquier, which have already been described for the Catoctin Valley, occur in small areas and are farmed in Harbaugh Valley. The portion of the Ashe* series of the 1919 survey which is on the mountain slopes has been reclassified as the Highfield series. It is a moderately deep to shallow soil with yellowish-brown surface and light colored friable subsoil. It occurs on rolling to very steep terrain. It has fairly high fertility, but slope and exposure limit its agricultural usefulness. The stony type includes a sizeable proportion of the total area.

The Porters* series of the 1919 survey has been eliminated from this area by recent changes in classification. The mountainous part of it has been renamed Clifton. This soil has brown surface and weak reddish-brown subsoil which is slightly compact. It is mostly steep but a few areas are smooth enough to be good cropland. It is a good soil for pastures and orchards.

Along some of the mountain slopes bordering the Middletown Valley and on the east slope of Catoctin Mountain, are very loose erodible soils derived from the weathering of schist. The Talladega* soils are associated with talcose schist bedrock and the Chandler* with mica schist. Both occur on rolling to steep land and when cultivated suffer severe damage by gully erosion. In adjacent areas a mixture of quartzite or sandstone with the schist gives rise to a soil mapped as Edgemont-Chandler complex. It is mostly forested as the stony types predominate. On much of the mountain area, sandstone or weak quartzites are the principal soil material and the soils are mapped in the Dekalb* series. This soil is mostly stony and ranges from moderately deep to shallow. Natural fertility is low, but because most of it has never been cleared, a high proportion has retained a good amount of organic matter in the surface soil and is fairly good forest land. The soil ranges from moderately deep to shallow.

Associated with the Eyler is a very shallow soil, the Catoctin series, which has already been described for the Catoctin Valley. The Hazel series is a similar but more erodible soil associated with Chandler and Talladega.

Rough stony land is associated with all of the parent rocks of the area, although it is most prevalent with the sandstones and quartzites. It is not suitable for cropland or pasture, and the shallowness of the soil reduces tree growth. The roughness of the terrain is also a drawback in forestry management.

This area includes some of the Braddock and Thurmont series described for the Triassic Upland area. They occur along valley edges and are not extensive. Along some of the streams, but above overflow, are deposits of alluvium which are mostly of sandstone origin, but include some other rocks. The well drained soil on this material is classed as Adamstown. In the 1919 soil survey of Frederick County it was included with Pope sandy loam*. The remainder of the Pope sandy loam of that survey has been included with the Congaree and Codorus gravelly loams. The Congaree gravelly loam is well drained. It resembles the Congaree mapped in the Piedmont Upland and Catoctin Valley except for having a high proportion of sandstone gravel and being lower in natural fertility.

IMPERFECTLY DRAINED SOILS

Because of the steep slopes of most of the area, imperfect and poorly drained soils are not extensive, but they occupy much of the land on gentle slopes. On Catoctin Mountain west of Lewistown is a flat with areas of Cookport stony silt loam which is derived from sandstone. It has a hardpan at a depth of about 16 inches and is frequently waterlogged. None of it is cleared for cultivation. Associated with it are small poorly drained areas of Nolo silt loam. In the alluvial valleys the imperfectly drained soil above normal overflow is Roddy. Most of it is gravelly and some is stony. It is underlain by compact silty clay loam which hinders internal drainage. It may be flooded occasionally. Its use for crops is limited unless it is artificially drained. Areas of this soil extend into the Triassic Upland along streams leaving the mountains.

On slightly lower areas along the streams is Codorus gravelly loam which is subject to frequent flooding and has an intermittently high water table.

POORLY DRAINED SOILS

In coves around streamheads in the mountains are small areas of poorly drained soils on usually deep colluvial material, or occasionally on residual material. Where the parent material is mainly sandstone and quartzite, the soil is classified as Lickdale. In areas of schist and metabasalt, the poorly drained soil is Lantz. Both soils have dark colored surfaces and are waterlogged most of the time. Neither has been farmed in this area.

On terraces along streams in the mountains and extending into the Triassic Upland, the poorly drained waterlogged soil is classified as Jimtown. It has a dark grayish-brown silty surface and gray mottled with yellow silty clay loam subsoil. Much of it is gravelly or cobbly. Some has been farmed, mostly for hay and pasture. Many of the ponds formerly used for rearing goldfish in this section were located on this soil.

A few areas of alluvial soils in the mountains are so variable in texture, drainage and stoniness that they are mapped as alluvial soils, undifferentiated.

AGRICULTURAL PRODUCTION

The importance of agriculture to these two counties and some of the characteristics of the local farming are shown by data from the 1940 Census for Agriculture, given in Table 2.

TABLE 2

*Agricultural Data for Carroll and Frederick Counties**

	Unit of measure	Carroll County	Frederick County	Total
Number of farms April 1, 1940	No.	3,188	3,465	6,654
Approximate land area	Ac.	291,840	424,960	716,800
Proportion in farms	Pct.	88.1	81.4	84.1
Average size of farms	Ac.	80.6	99.8	90.6
Cropland harvested, 1939	Ac.	145,726	189,622	335,348
Plowable pasture, 1939	Ac.	31,262	59,924	91,186
Woodland on farms, 1939	Ac.	35,995	42,796	78,791
Value of farms (land and buildings, 1940)	Dol.	15,837,825	21,674,644	37,512,469
Average value per farm (land and buildings, 1940)	Dol.	4,968	6,254	5,637
Total value of all farm products, 1939	Dol.	4,980,302	6,407,239	11,387,541
Proportion of tenancy, 1940	Pct.	20.2	26.3	23.4
Corn grown, 1939	Ac.	37,440	53,642	91,082
Winter wheat threshed, 1939	Ac.	38,408	54,790	93,198
All hay, exclusive of sorghums, 1939	Ac.	40,048	51,160	91,208
Barley threshed, 1939	Ac.	8,842	13,747	22,589
Irish potatoes, 1939	Ac.	1,231	2,841	4,072
Vegetable crops harvested for sale, 1939	Ac.	10,754	3,598	14,352
Clover seed harvested, 1939	Ac.	3,888	9,081	12,969
Cows and heifer milked, 1939	No.	15,559	26,753	42,312
Milk produced, 1939	Gal.	9,741,597	17,145,614	26,887,211

* Taken from the 1940 Census for Agriculture, U. S. Bureau of Census.

The most striking thing about the land use figures is the almost equal acreages of corn, wheat and hay which together make up 82 per cent of all the cropland. This illustrates the prevailing crop rotation of corn-wheat-hay, although there are many exceptions in individual farm practice. The vegetables harvested for sale are mostly sweet corn, peas and tomatoes. They are nearly all marketed at local canneries. According to census definition, over one-third of the farms in the two counties are dairy farms, almost a third produce mainly for home use, and the remaining third are distributed among other types in the following order: cash field crop farms, poultry farms, livestock farms, vegetable crop farms, and fruit farms.

AREA OF SOIL TYPES MAPPED IN FREDERICK COUNTY AND IN MONOCACY WATERSHED PORTION OF CARROLL COUNTY

Soil group, soil type*	Area in Frederick County	Area in Monocacy Watershed portion of Carroll County	Total area	Area of cropland
PIEDMONT UPLAND				
Deep, well drained residual soils				
Chester loam	1,759	1,162	2,921	2,496
Elioak silt loam	365	89	454	407
Elioak gravelly loam	102	—	102	75
Conestoga silt loam	1,563	1,412	2,975	2,617
Strasburg silt loam	1,242	1,308	2,550	2,171
Nason silt loam	645	—	645	235
Urbana silt loam	3,655	214	3,869	3,162
Urbana stony silt loam	28	—	28	—
Moderately deep, well drained residual soils				
Glenelg loam	1,392	899	2,291	1,914
Glenelg gravelly loam	12,572	5,689	18,261	13,585
Glenelg silt loam	5,180	5,788	10,968	9,249
Cardiff slate loam	6,954	—	6,954	4,998
Cardiff channery loam	1,961	—	1,961	809
Edgemont channery loam	1,192	—	1,192	592
Edgemont stony loam	988	—	988	63
Shallow, well drained residual soils				
Manor slate loam	55,174	54,421	109,595	74,470
Manor gravelly loam	10,023	959	10,982	6,758
Manor stony loam	847	11	858	99
Linganore slate loam	13,119	5,408	18,527	11,218
Linganore gravelly silt loam	1,346	—	1,346	598
Linganore stony loam	328	5	333	16
Brandywine gravelly loam	1,504	—	1,504	595
Urbana slaty silt loam, shallow ph.	6	—	6	6
Well drained terrace soil				
Wickham silt loam	49	64	113	110
Well drained floodplain soil				
Congaree silt loam	1,374	47	1,421	678
Congaree gravelly loam	486	—	486	104
Imperfectly drained colluvial soils				
Glenville silt loam	5,317	3,251	8,568	4,787
Glenville stony silt loam	295	—	295	31
Orange silt loam	617	—	617	385
Imperfectly drained terrace soil				
Altavista silt loam	142	265	407	240

AREA OF SOIL TYPES MAPPED IN FREDERICK COUNTY AND IN MONOCACY WATERSHED PORTION OF CARROLL COUNTY—*Continued*

Soil group, soil type*	Area in Frederick County	Area in Monocacy Watershed portion of Carroll County	Total area	Area of cropland
Imperfectly drained floodplain soil				
Codorus silt loam	7,846	2,492	10,338	2,148
Codorus gravelly loam	38	—	38	26
Poorly drained upland soils				
Worsham silt loam	1,629	1,430	3,059	1,183
Worsham stony silt loam	549	—	549	17
Lantz silt loam	852	37	889	123
Poorly drained terrace soil				
Roanoke silt loam	9	25	34	20
Poorly drained floodplain soil				
Wehadkee silt loam	6,643	1,929	8,572	852
MIDDLETOWN VALLEY				
Deep, well drained residual soils				
Myersville loam	20,577	—	20,577	16,067
Myersville gravelly loam	661	—	661	614
Myersville silt loam	7,960	—	7,960	7,022
Myersville stony loam	479	—	479	24
Fauquier loam	1,753	—	1,753	1,595
Fauquier gravelly loam	2,085	3	2,088	1,781
Fauquier silt loam	7,043	—	7,043	6,180
Shallow, well drained residual soils				
Catoctin silt loam	2,903	—	2,903	1,767
Catoctin channery loam	420	—	420	267
Fauquier loam, shallow phase	288	—	288	201
Well drained, colluvial soil				
Meadowville silt loam	597	—	597	442
Well drained terrace soils				
Wickham gravelly loam	167	—	167	134
Waynesboro gravelly loam	351	—	351	101
Well drained floodplain soil (along Potomac River)				
Huntington fine sandy loam	736	—	736	35
TRIASSIC UPLAND				
Well drained upland soils				
Bucks silt loam	209	3,148	3,357	2,985
Norton gravelly loam	2,332	—	2,332	1,792
Norton stony loam	116	—	116	—

AREA OF SOIL TYPES MAPPED IN FREDERICK COUNTY AND IN MONOCACY WATERSHED PORTION OF CARROLL COUNTY—*Continued*

Soil group, soil type*	Area in Frederick County	Area in Monocacy Watershed portion of Carroll County	Total area	Area of cropland
Athol gravelly loam	6,473	—	6,473	5,661
Athol stony loam	366	—	366	200
Athol gravelly loam, yellow subs. ph.	1,831	—	1,831	1,554
Montalto loam	62	—	62	45
Montalto silty clay loam	416	—	416	362
Montalto stony clay loam	977	15	992	245
Moderately deep, well drained residual soils				
Penn silt loam	20,528	11,077	31,605	26,923
Penn loam	7,404	4,891	12,295	10,206
Penn gravelly loam	4,974	2,138	7,112	5,321
Penn gravelly sandy loam	202	1,863	2,065	1,459
Lansdale loam	56	90	146	144
Lansdale sandy loam	—	162	162	133
Penn-Lansdale loam	2,063	939	3,002	2,445
Shallow, well drained residual soil				
Penn shale loam	15,358	12,710	28,068	21,363
Steinburg shale loam	86	78	164	104
Steinburg channery loam	73	652	725	555
Legore silty clay loam	161	—	161	127
Legore gravelly silty clay loam	577	21	598	236
Legore stony clay loam	376	—	376	97
Well drained colluvial soils				
Braddock gravelly loam	2,679	—	2,679	1,632
Braddock cobbly loam	539	—	539	323
Braddock stony loam	189	—	189	—
Thurmont gravelly loam	1,290	—	1,290	743
Thurmont cobbly loam	579	—	579	232
Thurmont stony loam	1,150	—	1,150	58
Well drained terrace soil				
Birdsboro silt loam	1,111	704	1,815	1,413
Birdsboro gravelly loam	87	36	123	109
Well drained floodplain soil				
Bermudian silt loam	1,310	407	1,717	637
Bermudian fine sandy loam	195	—	195	104
Imperfectly drained residual soils				
Readington silt loam	5,609	3,385	8,994	6,856
Lehigh silt loam	20	—	20	20
Lehigh gravelly loam	1,055	—	1,055	743
Iredell silt loam	290	—	290	207
Iredell stony clay loam	48	—	48	16

AREA OF SOIL TYPES MAPPED IN FREDERICK COUNTY AND IN MONOCACY WATERSHED PORTION OF CARROLL COUNTY—*Continued*

Soil group, soil type*	Area in Frederick County	Area in Monocacy Watershed portion of Carroll County	Total area	Area of cropland
Imperfectly drained terrace soils				
Raritan silt loam	465	510	975	737
Imperfectly drained floodplain soil				
Rowland silt loam	2,062	1,265	3,327	860
Poorly drained residual soils				
Croton silt loam	4,004	2,576	6,580	4,351
Stanton silt loam	128	61	189	74
Watchung silt loam	69	58	127	20
Poorly drained terrace soil				
Lamington silt loam	51	145	196	124
Poorly drained floodplain soil				
Bowmansville silt loam	580	575	1,155	297
FREDERICK VALLEY				
Deep, well drained residual soils				
Duffield silt loam	17,774	—	17,774	15,518
Duffield gravelly silt loam	389	—	389	297
Frankstown shaly silt loam	1,466	—	1,466	1,352
Hagerstown silt loam	1,917	1,157	3,074	2,534
Hagerstown loam	5,469	27	5,496	4,619
Hagerstown gravelly loam	2,699	538	3,237	2,924
Hagerstown stony loam	1,447	—	1,447	1,169
Hagerstown sandy loam	3,977	—	3,977	3,161
Hagerstown gravelly sandy loam	806	—	806	728
Moderately deep, fairly well drained residual soils				
Edom shaly silt loam	383	—	383	355
Well drained colluvial soils				
Araby silt loam	475	3	478	370
Emory silt loam	52	110	162	139
Well drained terrace soils				
Elk loam	926	—	926	726
Elk gravelly loam	423	—	423	262
Well drained floodplain soil				
Huntington silt loam	2,714	2	2,716	1,117
Imperfectly drained residual soil				
Colbert silt loam	342	—	342	245

AREA OF SOIL TYPES MAPPED IN FREDERICK COUNTY AND IN MONOCACY WATERSHED PORTION OF CARROLL COUNTY—*Continued*

Soil group, soil type*	Area in Frederick County	Area in Monocacy Watershed portion of Carroll County	Total area	Area of cropland
Imperfectly drained colluvial soil				
Wiltshire silt loam	2,730	438	3,168	2,522
Imperfectly drained terrace soil				
Captina silt loam	100	—	100	36
Imperfectly drained floodplain soil				
Lindside silt loam	2,278	825	3,103	925
Poorly drained upland and colluvial soil				
Guthrie silt loam	131	33	164	132
Poorly drained terrace soil				
Robertsville silt loam	24	—	24	7
Poorly drained floodplain soils				
Melvin silt loam	745	237	982	210
Dunning silt loam	188	—	188	129
APPALACHIAN MOUNTAINS				
Moderately deep, well drained soils				
Clymer loam	50	—	50	—
Clymer shale loam	89	—	89	—
Clymer stony loam	1,290	—	1,290	—
Highfield loam	902	2	904	747
Highfield channery loam	12,148	—	12,148	7,701
Highfield stony loam	18,021	—	18,021	689
Clifton gravelly loam	3,769	—	3,769	2,346
Clifton silt loam	3,832	—	3,832	3,155
Clifton loam	658	—	658	544
Clifton stony loam	4,320	—	4,320	113
Talladega slate loam	593	—	593	203
Talladega silt loam	374	—	374	173
Talladega stony loam	2,708	—	2,708	1,242
Chandler silt loam	2,571	—	2,571	1,796
Chandler slate loam	1,727	—	1,727	1,126
Chandler stony loam	503	—	503	7
Edgemont-Chandler channery loam	1,920	—	1,920	550
Edgemont-Chandler stony loam	18,167	—	18,167	68
Dekalb loam	182	—	182	128
Dekalb stony loam	3,199	—	3,199	11
Shallow, well drained residual soils				
Hazel silt loam	12	—	12	10
Rough stony land, Dekalb material	2,121	—	2,121	36
Rough stony land, Highfield-Catoctin material	5,903	—	5,903	22
Rough stony land, Edgemont-Chandler material	7,714	—	7,714	14

AREA OF SOIL TYPES MAPPED IN FREDERICK COUNTY AND IN MONOCACY WATERSHED PORTION OF CARROLL COUNTY—*Concluded*

Soil group, soil type*	Area in Frederick County	Area in Monocacy Watershed portion of Carroll County	Total area	Area of cropland
Well drained terrace soil				
Adamstown gravelly loam	164	—	164	95
Adamstown silt loam	187	—	187	100
Adamstown cobbly loam	144	—	144	57
Imperfectly drained residual soils				
Cookport silt loam	15	—	15	—
Imperfectly drained terrace soils				
Roddy gravelly loam	781	8	789	364
Roddy stony loam	315	—	315	34
Poorly drained colluvial soil				
Lickdale silt loam	57	—	57	6
Lantz stony loam	688	—	688	32
Poorly drained terrace soils				
Jimtown silt loam	299	—	299	47
Jimtown gravelly silt loam	85	1	86	24
Jimtown cobbly silt loam	545	—	545	57
Poorly drained floodplain soil				
Alluvial soils, undifferentiated	618	—	618	12
Miscellaneous				
Made land	161	—	161	—
Quarries, etc	125	55	180	—
Cemeteries	178	53	231	—
Water	2,199	263	2,462	—
Other areas not classified for soil types	50	—	50	—

* Total extent of a soil type is listed in one place although the soil may occur in two or more of the areas.

FORESTS OF CARROLL AND FREDERICK COUNTIES

BY

JOSEPH F. KAYLOR

The Forests of Carroll County

Carroll County is essentially agricultural in character. Only 13 per cent of it is in forest, and 76 per cent is in improved farm land. The surface is somewhat broken by irregular valleys and rounded hills. Parr's Ridge, which extends northeast and southwest through the central part of the county, is the most prominent elevation. Along this ridge, and to the east of it, are found most of the county's woodlands practically all of which are included in farms.

A striking feature of these woodlands is that about 99 per cent are pure hardwood stands. Only in rare instances is pine present. Because the soils of Carroll County are almost uniformly good, the forest growth in most places is characterized by tall, well-proportioned trees. Principal commercial species are white and red oaks, tulip poplar, and hickory.

A stable demand for forest products in the county is supplied in part by its woodlands. In order of production and value, lumber ranks first, with railroad ties second, and cord-wood third. Then follow poles, shingles, pulpwood, posts, and export logs.

The Forest Conservancy District Act of 1943 provides for rules of cutting practice designed to favor young growth of the more valuable species and to eliminate unprofitable trees. Application of these rules, along with the protection from fire provided by the Department of State Forests and Parks, should, in a relatively few years, increase timber production by about 60 per cent. One more step in this direction would be to close farm woodlands to livestock.

The Forests of Frederick County

Frederick, the second largest county in the State, is essentially agricultural in character. The forests, which cover 28 per cent of the total area, are very largely confined to the western mountain section, and so are considerably centralized. The small percentage of woodland, coupled with the extensive demand for wood products, gives the forests of the county very real value as a natural resource.

A recent survey by the United States Forest Service shows that of the 433,130 acres comprised in the county, 124,800 acres are wooded. This estimate is preliminary, but is believed to be essentially correct.[1]

[1] A map of Frederick County on the scale of 1 mile to 1 inch showing the forested areas was published in 1913 by the Maryland Geological Survey.

DISTRIBUTION OF THE FORESTS

Two-thirds of the wooded area is in the western half of the county, the remaining portion of the woodland is, for the most part, in small holdings on farms. Many farms have no woodland upon them, and the owners are therefore dependent upon their neighbors for wood. Some farmers, just east of the Catoctin Mountains, have small woodlots located in the mountain section, detached from their farm property. The Monacacy Valley, extending north and south through the central part of the county, has a smaller percentage of woodland than any other section. The Middletown Valley, along Catoctin Creek, in the southern and southwestern part, is also nearly destitute of woodland. In the western mountain section the woodlands are mostly in large continuous areas, while in the eastern half of the county, along the gently rolling foothills, the woodlands are mainly in small, isolated holdings. Woodlands have been almost entirely cleared away from lands that can be cultivated, and are therefore confined to the mountain ridges and slopes and to the thin soils of the rocky ridges and hillsides on the farm area.

The second election district in which Frederick is located has less than 20 acres of woodland out of a total acreage of more than 14,000, or little more than one-tenth of one per cent; whereas in District No. 10, in the northwest section of the county, 57 per cent is wooded. Nine of the 26 election districts are less than 10 per cent wooded, while five are more than 40 per cent wooded.

It is not likely that there will be any marked changes in forest distribution for many years to come because of the rather clear-cut distinction that now obtains between farm soils and forest soils.

DESCRIPTION OF THE FORESTS

Hardwood forests prevail throughout the county. Pine, which is the only soft wood of note, is practically negligible, so far as the stand of timber is concerned. The only areas of consequence are those in the Catoctin Mountains, west of Thurmont, and here the pine is mixed with hardwood. The only pure stands are small patches near the Monocacy River, scattered through the central part of the county. A large number of different species of trees occur in the forests and their relative proportions in the stands tend to form rather distinctive forest types. In the mountain section, chestnut oak prevails along the tops and upper slopes of the ridges. Along the upper slopes, it is often mixed with scarlet and black oak. White oak, red oak, hickory and tulip poplar are the prevailing species on the lower slopes.

The original character of the forest has been greatly changed under use and abuse, particularly as the result of frequent and destructive forest fires. Practically the entire forest area of the county has been cut-over. A considerable portion has been cut over two or three times. At each cutting the more valuable species have been taken and often the undesirable species were left entirely, so that the relative proportion of the inferior species has increased. Originally the mountain forests consisted of about 50 per cent chestnut. The chestnut blight, a fungus disease attacking only the chestnut, reached this section of the State about 1912, and has now practically destroyed the chestnut as an important timber tree. Its place in the forest is being taken principally by the oaks, but where pure stands of chestnut occurred, which was over a considerable part of the area, the replacement is a slow process. The fire damage in the mountains has been particularly severe, resulting in serious deterioration of the stands, not only causing a low timber production, but very greatly reducing the quality of the product.

A large area of the forests in the vicinity of Catoctin Furnace was operated for more than 100 years prior to 1890 for the production of charcoal in supplying the iron furnaces at that point. The furnaces required a continuous supply of wood, which was obtained by cutting clean each year a portion of the forest and coming back again for another cutting at intervals of from 25 to 35 years. This resulted in even aged sprout forests, coming up from the stumps, following cutting. Trees of the greatest sprouting capacity, such as chestnut and the oaks, thrive under this system, and where fires were kept out maximum wood production was maintained. It is interesting today to note the old charcoal beds and the wagon roads built for taking out the charcoal many years ago. Outside of the mountain areas, where the woodlands are somewhat isolated, fire damage has been slight, and as a result the woodlands are in better condition, alhough they have suffered much from destructive methods of cutting and from excessive grazing.

Today, the greater part of Catocin Ridge is in public ownership, as represented by the Catoctin Recreational Area of 9873 acres, at present under the jurisdiction of the U. S. Department of the Interior; the Frederick City Watershed of 6000 acres; and Gambrill State Park of 1088 acres, a gift to the State from the City of Frederick, developed in the nineteen-thirties by the Civilian Conservation Corps.

IMPORTANT TIMBER TREES AND THEIR USES

Practically every species of tree in the county is used in some way, if only as firewood on farms. Commercially, however, the number of species that are sold are limited, although often, as in the case of the oaks, one recognized commercial species will include many different botanical species. The list following contains the most important commercial species in the county.

Oaks.—The species of oak are usually sold in two classes—the red and white oaks, of which the white is more important. Approximately 65 per cent of the cut of timber from the county is oak.

White Oaks.—The white oak class of timber is one that possesses strength and durability to a remarkable degree. The true white oak is unsurpassed, but there are several different species which are very similar to it and cannot be recognized except by experts. This fact leads to the grouping of the oaks on the market. This group includes, besides the true white oak, which forms 60 per cent of what is cut, the chestnut oak, about 20 per cent, with the post oak and swamp white oak making up most of the remainder.

The wood of the white oak, because of its toughness and durability, is especially adapted for use as a general construction timber. Much of it is cut for local use on farms. It is also very valuable as a railroad tie, as it can be used in contact with the ground without preservative treatment. It is exported for use as furniture wood, cooperage stock, car construction, framing, ties, and other uses.

Red Oaks.—The red oaks are inferior to the white oaks only in being less durable. This quality, however, affects the sale price. This group contains the true red oak, black oak, scarlet, pin oaks, and others less common. The red oak itself is the equal of white oak in all but durability.

The red oaks are cut for general farm timbers in the county, but are not used to the extent that the white oak is. A great amount of red oak is cut into railroad or trolley ties. For this use, however, it is necessary that the wood be given a preservative treatment. Red oak is also in demand for general construction, car stock, planking, furniture, and interior finish.

Chestnut.—This species of tree has been attacked by the chestnut blight to such an extent that its future as a commercial tree in the county seems doomed.

Tulip Poplar.—This wood enters but little in the production of lumber in the county, largely because of the absence of trees of saw log size. It does, however, make up the largest percentage of wood cut into pulpwood.

LUMBER AND TIMBER CUT

Lumber.—The lumber cut consists almost entirely of hardwood, of which 65 per cent is oak, 20 per cent chestnut, and 15 per cent miscellaneous, including tulip poplar, hickory and maple. Pine and hemlock represent less than 2 per cent of the total cut.

Most of the timber is cut by portable mills, which operate only a short period during the year, making frequent moves as each tract is cut over. A few of the mills operate by water power, and do a small custom business.

Railroad Ties.—The cutting of railroad ties constitutes one of the chief woods operations. The high prices obtained have stimulated tie production, so that much timber that would ordinarily have gone into lumber is converted into sawed ties. The high cost of labor and the wastefulness of the operation have nearly eliminated hewn ties in favor of sawed ties. A considerable quantity of short board is derived from the slab cuts. Chestnut, red oak, and white oak are the principal woods used.

Staves.—Staves are made from bolts which are cut in five-foot lengths in the woods, any hardwoods being used. The wood is sold by the cord and trees as small as five inches in diameter are used. The stave business furnishes an excellent means of utilizing small blight killed chestnut timber.

Pulpwood.—The production of pulpwood is on the increase. This consists mostly of poplar, with a small percentage of butternut. The bark is peeled and the wood cut into five-foot lengths and sold by the cord of 160 cubic feet.

Shingles.—Small portable shingle mills operate in the county. Shingles are used for the most part locally. Shingle wood is cut into short bolt lengths of 16 to 20 inches, blocks of 10 to 16 inches in diameter being preferred.

Lath.—Lath are usually cut in connection with lumbering operations, using slab wood and other parts not suitable for lumber.

Cordwood.—In the mountain sections, within easy hauling distances of the towns, where it is used for fuel, and the lime kilns, where it is used in burning lime, a considerable quantity of cordwood is cut each year. This consists, principally, of oak, although chestnut and other specis are used to a considerable extent.

HOME USE OF WOOD AND TIMBER

Frederick County consists mainly of highly developed farms. A large quantity of wood and timber is used on the farms for building material, fuel wood and fencing. This represents material cut from the forests in addition to that sold from the woodlands.

Building Material.—This is in addition to sawed lumber and comprises hewn timbers, or those used in the round for various home buildings, such as barn frames, stables, and other structures on the farm.

Fuel Wood.—Many farms use coal for fuel, but most use wood exclusively, or to a limited extent. This consists, in part, of dead and down wood, but is mostly green, growing timber.

Fence Posts.—This includes the posts used for post-and-rail fences, and also those used for wire fences. Where locust is easily obtainable, it is preferred to all other woods.

FOREST PROTECTION

The woodlands of Frederick County are today producing less than half of a full timber crop, because of destructive agencies, which for more than 150 years have been operating in the forests. Chief among them are forest fires, destructive cutting methods, excessive grazing, and the ravages of insects and fungus diseases. At least three-fourths of this damage is preventable, and all forest owners and users of the forest (which includes every resident of the county) should cooperate to protect the forest and to bring it up to its highest productive capacity.

Forest Fires.—The forest fire danger in Frederick County is very much intensified by reason of the fact that the great bulk of the woods is in a continuous body along the mountains. These areas get very dry during the spring and fall, and forest fires, once started, gain rapid headway and are difficult to control.

The fire record for 1944 shows an area burned over of 122 acres.

The State maintains a fire protective organization in the county, consisting of a number of forest wardens, forest guards, and district supervisors. It maintains four lookout towers for detecting forest fires quickly, and three mobile pumper units.

The forest wardens are regularly commissioned officers, with full authority to employ assistance, and use any means that may be necessary for controlling forest fires. Each landowner is required to do all he can to control fires on his own lands, but where he is unable to do so, the local forest warden should be promptly notified, so that measures may be taken without delay for preventing the spread of the fire to other property, or causing unnecessary damage on the property where it originated. Everyone should cooperate with the forest wardens in suppressing forest fires, which are the chief enemy of the forest. In Frederick County, three-fourths of the fires are the result of carelessnes, or deliberate intent to burn. It is only with the support of woodland owners in fire prevention that this public menace may be abated. Fire prevention regulations have been established by the Commission of State Forests and Parks, and all woodland owners should acquaint themselves with these.

Destructive Methods of Cutting.—It has been the practice for generations on the part of most woodland owners, to cut over their woodlands at frequent intervals, taking out the best and most saleable products, with little or no thought to the succeeding growth and future productiveness of the woodlands. This repeated cutting has resulted in forest of inferior value, made up of a large proportion of inferior species, and the defective and crippled trees have been left to take possession of the ground, to the exclusion of more valuable growth. A radical change in the method of handling the forest is necessary before increased production and improvement of quality are possible. The native species of trees in the county, and the conditions of growth, are excellent for timber production, if these natural conditions are only given a fair chance. To restore production it will be ncessary to work for the reproduction in the forest of the more valuable species and the elimination of the crooked and defective trees and the species of less value. This can be accomplished by improvement cuttings, which, while producing considerable revenue in low-grade material, will greatly improve the character and composition of the forests. The damage occasioned by surface fires, resulting in a large percentage of fire scarred trees, which give no promise of valuable timber production, is accountable, in a large measure, for the low timber production. The removal of these fire damaged trees is essential to any improved system of management.

The Legislature of 1943 passed what is known as the Forest Conservancy Districts Act, which authorizes the Commission of State Forests and Parks to establish rules of forest practice on all privately owned timberlands throughout the State. Seven regulations have been established. Information as to these may be obtained from the District Forester, Court House, Cumberland, Maryland.

Grazing.—It is common practice among the farmers of the county to include the woodland in the permanent pasture. This is particularly true where the woodlands are in small areas, as in the eastern and southwestern portions. Pastured woodlands are never in the best condition for timber growth, because the soil becomes hard and dry from the constant trampling of the cattle, the seed bed is destroyed, and the growth of the trees seriously checked, if not altogether stopped. Under these unfavorable conditions, the woodland becomes open and very much understocked. This, if continued, will ultimately result in reducing timber production to a minimum. The small amount of pasture is poor pay for the loss in timber production. Since the woodland is usually on rocky ridges, or steep slopes with thin soil not suited for grass land or farm land, pasturing, if permitted at all, should be so regulated as not to disturb the forest cover.

Insects and Fungus Diseases.—No serious insect attacks have affected the forest trees in recent years. Some years ago, and at intervals since that time, the black locust has suffered somewhat from the attacks of an insect, one of the leaf miners, which works between the epidermal layers of the leaf, eating away the tissues and causing the leaf to turn a rusty brown. This occurs usually in late summer, after the trees have made their principal growth of the season, so that the danger is not serious, although the discoloration and dropping of the leaves is rather alarming at the time.

There has been more or less defoliation of trees by caterpillars, but usually the danger from this source in the forest is very slight, the chief damage being done to shade trees, and even there the natural enemies of such insects usually hold them in check.

The most serious tree disease that has ever occurred in the county, or in the State, is the chestnut blight (Endothia parasitica), which attacks the inner bark and cambium wood of the tree, first appearing as a small canker which spreads horizontally, as well as vertically, until the portion of the tree attacked, whether it be a branch, or the trunk itself, is completely girdled and the circulation cut off. This causes the death of the tree beyond the girdle, and when a larger number of these cankers appear on the same tree, it is certain death, although the complete death of the tree may not result for two or three years. While the disease is fully known and its method of attack fully ascertained, there is no known method of control. The loss is tremendous because of the fact that the chestnut in Frederick County constituted a larger proportion of the forest than any other single species, and, in addition, was probably the most useful tree of all, because of its adaptability to many purposes, its durability, and its special use for telephone and telegraph poles, for which there is no local substitute.

FOREST MANAGEMENT

The 124,800 acres of woodland in the county could supply all the timber needs, if it were fully productive. Natural conditions of growth are exceptionally good, and the species represented in the forest are among the most valuable species growing in the State. There is a good demand for timber, excellent transportation facilities, and good markets.

However, due to forest fires in the past, to those annually recurring, to destructive methods of cutting, to excessive grazing, and to the ravages of the chestnut blight, the forest lands are producing on an average less than 40 cubic feet of wood per acre per annum, whereas they should be producing at least 90 cubic feet. This high production can be secured and maintained on lands protected from fire, and properly managed. This, in short, is what forestry is seeking to accomplish.

The destructive agencies have been operating so long and with such deadly effect, that it will take many years in the case of the badly abused woodland to bring it back to full production. Certain steps will be required, and should be instituted without delay, in orderly fashion, to restore full productiveness. The fire menace must be reduced to a minimum by carrying out the recommendation for forest fire protection. Open and unproductive places in the woodland must be restocked so that every square foot of land will be productive. Where the woodlands, due to past mismanagement and the damage from fires, consist of a large proportion of fire scarred, or crooked and defective trees, or those of poor species, these must be eliminated, and replaced by good specimens of more valuable species. This process will ordinarily be a gradual one, rather than accomplished in one operation. No two woodlands are exactly alike, and the treatment of each must be regulated to the conditions and purposes of management. An examination of the woodland should be made by an expert, and a plan of management worked out on the ground designed to give the best results.

The Department of State Forests and Parks offers to timber owners a marking service designed to ensure that only the trees that should be removed from a stand are taken out. Up to 25 acres, no charge is made for this service. Additional acreage is marked at a charge of $8.00 per day.

The haphazard methods of cutting practiced in the past must give way to a cutting system that will keep the forests continuously productive. Where timber is sold there should be specific contract between the seller and the buyer as to just what trees may be cut and what trees are to be reserved by the owner. Timber is increasing so rapidly in value that the young immature growth, which must be preserved and protectd for the next timber crop, is of high prospective value, a fact which should be fully recognized in making the timber contract.

FOREST PLANTING

There are probably between 30,000 and 40,000 acres of waste land in the county upon which grow no crops of value. With the exception of a small percentage suitable for permanent pasture, most of it is better adapted for timber growing than for any other purpose. Under present conditions, it is coming back in timber growth, if at all, very slowly. It must be planted in forest trees to secure its highest usefulness, and bring it back to immediate productiveness. Some of this land represents rocky ledges, gullied hillsides, or swampy portions of the farms which would support a good tree growth, if planted in suitable species. Of the great variety of native trees indigenous to the county, species may be found suitable for any conditions that exist, and profitable timber crops can be produced on lands that are not productive for other purposes. Some of the farms in the valley, upon which there is no timber, would be made more valuable by planting a small woodlot, which often can be located on the windward side of the farm house and barns, so as to give, in addition to a supply of wood for the farm, the added protection of a windbreak—a valuable asset to any farm. Often the plantation may include species suitable for fence posts and other farm timbers, in addition to the use of the woodlot for fuel wood.

Forest planting need not be confined to the waste lands on the farm, for frequently the existing woodland is very much understocked. There are open, unproductive areas on which the planting of trees, or of tree seeds, is needed in order to insure full production. For this purpose, it is necessary to use species of trees that will grow under the shade of other trees, like the white pine, Norway spruce, oaks, and sugar maple.

TREES FOR FOREST PLANTING

Black locust (Robinia pseudacacia), also called yellow locust, or simply "locust," is a native tree of rapid growth, producing a heavy, hard, durable wood, prized above all other species for fence posts. It casts so little shade that grass and weeds will grow under the trees and compete for moisture and soil fertility. For this reason, and also because of possible attack from the locust borer, it is advised to plant with it some other species of somewhat slower growth, that will endure shade, and at the same time more completely shade the ground, such as white pine or red oak. The trees should be spaced 6 x 6 feet in alternate rows, with a row of white pine or red oak, whichever is used in the mixture, on the outside of the plantation. On good soils the locust will grow two to four feet in height each year. Fence posts will be produced in about 15 to 20 years, leaving the other species to produce a timber crop some years later. One-year-old locust seedlings should generally be used for establishing the plantation. On open land no previous preparation of the soil is necessary for the planting.

White pine (Pinus strobus) is a native tree growing naturally in the mountain section, but it is adapted for planting in almost any section of the county. It is a rapid growing tree, averaging from one to two feet in height each year, and produces a soft, even-grained wood, useful for many purposes. It will produce saw timber in 30 or 40 years on good soil. It should be planted, ordinarily, in pure stands 6 x 6 feet apart, and small trees from four to six inches in height may be used.

Red oak (Quercus rubra) is one of the most valuable hardwoods for forest planting. It is a native tree, the most rapid growing of the oaks, producing a heavy, hard, strong wood, very useful on the farm for general construction purposes and for fuel wood. The red oak is fairly tolerant of shade, and therefore useful for underplanting in woodlands in need of reinforcement. The best method of propagation is by planting the seeds, two in each hole, and afterward thinning to one tree. In establishing a plantation, a spacing of 5 x 5 feet is recommended when seed is used, and 6 x 6 feet when seedlings are planted. One-year-old seedlings are sufficiently large for forest planting. Red oak should not be planted on thin, dry soil.

White ash (Fraxinus americana) is a tree of rapid growth on rich, moist soil, producing a wood of high value. It is especially adapted for planting on bottom lands, subject to overflow, which would render them unfit for agricultural crops, and may be planted in a pure stand, using one-year seedlings and spacing them 6 x 6 feet. The wood is very heavy, elastic, tough, and straight grained. It is generally used in the manufacture of agricultural implements, tool handles, sporting goods and vehicles, and is saleable in small size bolts, which can be grown on a comparatively short rotation.

SHADE TREES

While the care and protection of shade trees is not generally associated with forestry in Maryland, the public shade tree work is handled by the Department of State Forests and Parks, under what is generally known as "The Roadside Tree Law," Chapter 824, Acts of 1914.

The planting and care of shade and ornamental trees on the home grounds is of the highest importance in increasing comfort and attractiveness. The planting of windbreaks is one of the most important measures for protecting the home and other farm buildings, and in sheltering the live stock from the sweep of the winter winds. For this purpose there should be two or three rows of evergreen trees planted on the windward side of the buildings. The best species for the purpose is Norway spruce or white pine. If the former is used, the trees should be planted in rows 10 feet apart, and eight feet apart in the rows. If white pine is used, the spacing should be 10 feet apart in the rows.

In the planting of the home grounds, there is a wide selection of trees to draw upon, sufficient to satisfy every taste and every requirement. There are two things to remember in home planting:

First, do not plant trees too close to the house. They must be given sufficient room to grow without crowding, and it is always best to have plenty of air space around the building.

Second, in selecting the trees for planting, look for permanent results. The most rapid growing trees are often the least desirable when fully grown, and likely to deteriorate rapidly after maturity, when they are the most needed. To this class belong the Carolina poplar, silver poplar, willow and ailanthus, and to a somewhat lesser degree, silver maple and red maple. Among the best trees to plant are the American elm, sugar maple, sycamore maple, red oak, white pine, Norway spruce, Oriental plane, gingko and white ash.

The Department of State Forests and Parks, Annapolis, Maryland, maintains a State Forest Nursery from which trees suitable for forest and roadside planting are furnished at cost. A State nursery list is obtainable upon request.

FOREST TREES IN CARROLL AND FREDERICK COUNTIES

NATIVE FOREST TREES

Seventy-seven species of native forest trees are found in Frederick and Carroll counties. The northern red oak is found only in Carroll County, and table mountain pine, the scrub oak, the Spanish oak, the cucumber tree, and the red gum are found only in Frederick County. The list of native species which reach tree size is:

Conifers

Common name	*Scientific name*
White Pine	Pinus strobus
Scrub Pine (Virginia Pine)	Pinus virginiana
Pitch Pine	Pinus rigida
Table Mountain Pine	Pinus pungens
Hemlock	Tsuga canadensis
Red Cedar	Juniperus virginiana

Hardwoods

White Oak	Quercus alba
Chestnut Oak	Quercus prinus
Swamp White Oak	Quercus bicolor
Northern Red Oak	Quercus borealis maxima
Post Oak	Quercus stellata
Red Oak (Southern Red Oak)	Quercus rubra
Black Oak	Quercus velutina
Scarlet Oak	Quercus coccinea
Pin Oak	Quercus palustris
Scrub Oak	Quercus ilicifolia
Overcup Oak	Quercus lyrata
Burr Oak	Quercus macrocarpa
Shingle Oak	Quercus imbricaria
Black Jack Oak	Quercus marilandica
Spanish Oak	Quercus falcata
Chinquapin Oak	Quercus prinoides

Common name	*Scientific name*
Chestnut	Castanea dentata
Chinquapin	Castanea pumila
Tulip Poplar	Liriodendron tulipifera
Basswood	Tilia americana
Black Locust	Robinia pseudacacia
Mockernut Hickory	Carya alba
Pignut Hickory	Carya glabra
Shellbark Hickory	Carya ovata
Small Pignut Hickory	Carya microcarpa
Big Shellbark Hickory	Carya laciniosa
Black Walnut	Juglans nigra
Butternut	Jugland cinerea
Red Maple	Acer rubrum
Black Maple	Acer nigrum
Sugar Maple	Acer saccharum
Mountain Maple	Acer spicatum
Box Elder	Acer negundo
Cucumber Tree	Magnolia acuminata
Umbrella Tree	Magnolia tripetala
White Ash	Fraxinus americana
Black Ash	Fraxinus nigra
Red Ash	Fraxinus pennsylvanica
White Elm	Ulmus americana
Slippery Elm	Ulmus fulva
Red Gum	Liquidambar styraciflua
Wild Black Cherry	Prunus serotina
Fire Cherry	Prunus pennsylvanicum
Sycamore	Platanus occidentalis
Trembling Aspen	Populus tremuloides
Large Toothed Poplar	Populus grandidentata
Silver Poplar	Populus alba
Balsam Poplar	Populus balsamifera
Sour Gum	Nyssa sylvatica
Swamp Gum	Nyssa biflora
Red Mulberry	Morus rubra
Sassafras	Sassafras sassafras
Alder	Alnus rugosa
Paw Paw	Asimina triloba
Shadbush	Amelanchier canadensis
Black Birch	Betula lenta
Yellow Birch	Betula lutea
Red Birch	Betula nigra
Blue Beech	Carpinus caroliniana
Hackberry	Celtis occidentalis
Red Bud	Cercis canadensis
Dogwood	Cornus florida
Cockspur Thorne	Cragaegus crus-galli
Persimmon	Diospyrus virginiana
Beech	Fagus grandifolia
Witch Hazel	Hamamelis virginiana
Hop Hornbeam	Ostyra virginiana
Mountain Ash	Pyrus americana
White Willow	Salix alba
Black Willow	Salix nigra
Staghorn Sumach	Rhus typhina

INTRODUCED TREES THAT HAVE BECOME COMMON IN THE FOREST

Common name	*Scientific name*
Honey Locust	Gleditsia triachanthos
Silver Maple	Acer saccharium
Ailanthus	Ailanthus glandulosa
Osage Orange	Maclura pomiferum
Fringe Tree	Chionanthus virginica

CLIMATE OF CARROLL AND FREDERICK COUNTIES

BY

JOSEPH BILY, JR.

Climate is the average of daily weather conditions, which change from day to day Weather conditions include atmospheric pressure, temperature, humidity, cloudiness, sunshine, precipitation (rain, snow, sleet), and wind (direction and force); and their quantitative variations day by day and throughout the year. These factors are modified somewhat locally by the configuration of the earth's surface, variations in elevation and latitude, presence of large bodies of water and of forest areas, and the character of the soil.

Air masses, or areas of low and high pressure, in their eastward movements, are the causes of the variations in the daily weather conditions from precipitation to sunshine, from warmth to cold, and from storm to calm.

Weather Stations

The earliest known weather observations in Carroll County were made at Schellman's Hills, where the record began in January 1846. Observations at New Windsor were made in 1852.

The earliest known weather observations in Frederick County were made at Frederick, where the record began in October 1851. The station with the next longest record is Emmitsburg, where records began in January 1867.

Weather observation stations in Carroll and Frederick Counties have been under the supervision of the U. S. Weather Bureau during the past 50 years.

Weather observation stations within Carroll and Frederick Counties and their histories appear in table 1.

Woodstock, Baltimore County, Maryland, and its data are used as representative of extreme southeastern Carroll County.

The station of lowest elevation is Frederick, while State Sanatorium is the most elevated.

Temperature

Temperature is the most influential climatic factor affecting human activities. The apparent or sensible temperature, however, is modified greatly by the humidity or degree of saturation of the air, and by sudden shifts in the wind.

The normal diurnal variation of temperature is from a minimum at sunrise upward to a maximum in the mid-afternoon and then downward to the early morning minimum. The time of occurrence of minimum and maximum temperatures varies with the seasons. The greatest difference between the lowest and highest temperatures is on clear days, especially in the spring and fall months. Cloudiness reduces considerably the daily temperature range. On a rainy or snowy day the daily tem-

TABLE 1

List of Weather Recording Stations

Station	Latitude	Longitude	Elevation	Years of record	Observer
Carroll County					
			feet		
Bachman's Valley	39° 37′	76° 55′	860	Sept. 1893–Nov. 1909	J. M. Myers
				Feb. 1910–Mar. 1911	Elmer E. Yingling
				May 1917–July 1920	Clarence B. Myers
Fenby	39° 32′	77° 0′	950	Jan. 1893–Sept. 1894	William Fenby
Harney	39° 43′	77° 11′	500	Mar. 1899–Mar. 1900	Warren Hill
				Apr. 1900–Dec. 1907	Daniel Bowersox
Mt. Airy	39° 22′	77° 5′	813	Jan. 1872–Nov. 1874	Dr. E. A. Varmort
New Windsor	39° 31′	77° 6′	700	Jan. 1852–Mar. 1852	Prof. T. P. Nelson
				July 1852	
				Dec. 1852	
Sam's Creek	39° 30′	77° 3′	750	June 1871–July 1872	Francis J. Devilbiss
				May 1873–Nov. 1873	
				May 1874–Aug. 1874	
Schellman's Hills*	39° 23′	76° 58′	600	Jan. 1846–Dec. 1865	Dr. William Baer
					Miss Harriet M. Baer
Taneytown	39° 40′	77° 10′	500	Jan. 1891–May 1893	Dr. C. W. Weaver
				Oct. 1893–Dec. 1894	David H. Bowers
				July 1896–Aug. 1902	Prof. Henry Meier
				Aug. 1902–Sept. 1902	Prof. Henry K. Borbe
				Apr. 1906–Dec. 1910	R. A. Musbaund
				May 1911–Jan. 1912	James B. Galt
				Feb. 1912–Aug. 1912	Curtis H. Reid
Union Bridge	39° 34′	77° 10′	460	Mar. 1915–Dec. 1918	G. S. LaForge
				July 1919–Sept. 1919	Dr. Harry F. Baer
Westminster	39° 35′	77° 0′	770	Jan. 1893–Mar. 1893	John T. Cafsell
				Jan. 1895–July 1898	Prof. Roland Watts
				Sept. 1898–May 1899	Dr. Cleveland Abbe
				Oct. 1899–June 1901	Prof. Roland Watts
				June 1911–June 1913	George F. Morelock
				Dec. 1920–Sept. 1931	Prof. S. P. Caltrider
				Sept. 1931–Nov. 1931	Stewart N. Dutterer
				Apr. 1932–Dec. 1944	Harry J. Mathias
Baltimore County					
Woodstock	39° 20′	76° 53′	415	Dec. 1870–Dec. 1944	Woodstock College

TABLE 1—*Concluded*

Station	Latitude	Longitude	Elevation	Years of record	Observer
Frederick County					
			feet		
Frederick	39° 25′	77° 25′	297	Oct. 1851–Dec. 1859	Dr. Lewis H. Steiner
				Jan. 1854–June 1863	Henry E. Henshaw
				Jan. 1861–June 1863	J. K. Henshaw and
				Dec. 1865–Sept. 1866	Miss Harriet M. Baer
				Mar. 1869–Apr. 1872	
				Aug. 1871–Apr. 1872	Henry E. Henshaw
				Dec. 1888–Feb. 1892	McClintock Young
				Mar. 1892–May 1896	Woman's College
				July 1894–Mar. 1906	McClintock Young
				Apr. 1906–July 1910	Henry Trail
				Aug. 1910–May 1929	Charles S. Birely
				May 1929–May 1941	Arthur T. Brust
				May 1941–Dec. 1944	D. John Markey, Jr.
Monrovia	39° 23′	77° 17′	475	June 1906–Dec. 1917	J. H. Lawson
Mt. St. Mary's Seminary	39° 41′	77° 21′	720	Jan. 1867–Nov. 1873	Mt. St. Mary's Seminary
				Sept. 1875–Mar. 1887	
				Feb. 1888–Dec. 1944	
New Market	39° 23′	77° 17′	550	Aug. 1873–Oct. 1879	Dr. Howard Hanford Hopkins
				Sept. 1891–Aug. 1894	
				Nov. 1895–May 1906	
New Midway	39° 34′	77° 15′	485	Sept. 1886–Feb. 1888	George F. Smith
State Sanatorium	39° 43′	77° 27′	1460	May 1909–Dec. 1944	State Sanatorium
Unionville	39° 28′	77° 11′	450	July 1940–Dec. 1944	G. Plitt von Eiff, Jr.

* Two miles north of Sykesville.

perature range is slight. Clear sunny days, as a rule, are cooler than normal in autumn, colder than normal in winter, milder than normal in spring, and warmer than normal in summer. Cloudy and rainy days are warmer than normal in autumn and winter and cooler than normal in spring and summer. Snow on the ground lowers the temperature considerably due to more intense radiation from its surface during the night and the absorption of the heat of the sun's rays in melting the snow during the day. Furthermore, a snow cover prevents the radiation of heat from the earth and the penetration of frost into the ground, thereby protecting winter grains and other vegetation.

Variation in temperature from day to day is a climatic factor of great importance, especially to the weak and sickly. Large, especially sudden, changes in temperature within short periods are uncomfortable if not actually harmful. Such changes are

TABLE 2

Monthly and Annual Temperatures

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley													
Highest	36.9	39.1	48.3	55.0	66.5	71.6	76.9	76.2	69.9	58.7	47.2	35.5	53.3
Mean	29.2	28.0	40.3	49.6	60.8	68.8	73.8	71.3	64.8	52.8	41.6	30.6	51.0
Lowest	19.1	21.0	33.4	46.2	54.8	64.3	70.0	68.3	59.2	47.5	34.7	23.0	48.3
Frederick													
Highest	44.8	42.4	53.8	60.2	70.3	77.9	81.3	79.3	75.4	62.2	52.5	44.4	57.5
Mean	32.5	33.4	42.4	52.8	63.9	72.2	76.6	74.2	67.7	55.9	44.5	34.8	54.2
Lowest	20.4	23.6	32.9	44.5	57.6	65.7	71.6	68.0	62.5	49.7	40.0	27.4	51.2
Mt. St. Mary's Seminary													
Highest	43.0	42.4	51.8	58.3	69.8	75.8	80.4	76.6	72.6	61.1	52.0	42.4	55.9
Mean	31.2	32.4	40.6	51.8	62.3	70.3	75.2	72.8	66.3	55.1	43.5	33.6	52.9
Lowest	19.7	22.2	32.8	44.9	54.9	64.7	71.0	67.0	60.8	46.4	36.8	24.6	48.8
New Market—Monrovia													
Highest	41.1	41.8	50.1	58.2	68.8	78.8	80.0	77.0	71.8	60.4	50.6	41.3	55.6
Mean	31.5	31.2	40.8	51.9	63.1	71.2	75.7	75.5	66.8	55.1	43.5	33.6	53.3
Lowest	20.9	24.4	30.8	45.1	57.0	64.6	71.0	70.0	60.7	46.6	38.8	22.6	50.5
Schellman's Hills													
Highest	36.6	38.8	46.8	55.2	66.4	74.0	78.6	75.7	73.5	58.5	50.9	43.8	55.2
Mean	31.9	31.7	40.6	50.8	62.7	70.5	73.8	71.8	65.7	54.2	44.1	33.7	52.6
Lowest	18.9	24.0	35.3	44.2	57.6	66.0	70.3	68.3	61.2	50.4	39.9	29.0	49.8
State Sanatorium													
Highest	41.8	39.1	51.0	56.6	68.3	74.7	79.6	75.8	72.0	60.2	51.5	42.0	55.0
Mean	30.8	31.3	40.0	50.6	62.0	69.9	74.0	71.9	65.8	55.0	43.4	32.7	52.3
Lowest	17.0	21.0	33.2	46.0	55.0	65.2	70.9	68.1	60.9	47.8	37.3	23.3	49.2
Taneytown													
Highest	37.8	40.7	48.1	55.0	68.4	72.8	80.0	79.1	72.8	60.2	49.4	38.2	54.4
Mean	31.3	30.2	41.2	51.8	62.6	69.9	76.0	73.4	67.3	54.8	43.6	33.0	52.9
Lowest	21.5	22.8	35.0	46.2	56.8	63.2	72.0	70.4	64.1	48.8	37.0	25.2	50.2
Westminster													
Highest	43.0	40.0	52.2	59.7	70.4	76.6	78.0	73.3	73.3	61.2	52.6	42.5	56.4
Mean	31.1	31.7	40.4	49.9	61.1	68.9	74.2	71.1	65.4	53.8	43.4	34.1	52.0
Lowest	20.8	21.2	34.2	47.4	57.8	65.5	72.0	67.4	61.9	49.4	39.0	28.5	51.1
Woodstock													
Highest	44.5	43.4	54.4	59.4	69.0	76.6	80.6	77.4	72.8	63.2	52.3	42.7	57.8
Mean	32.2	33.2	41.5	52.1	63.1	71.0	75.2	72.9	66.3	54.9	43.7	34.4	53.4
Lowest	20.4	21.2	30.6	43.6	57.8	66.0	69.0	67.6	58.1	48.2	36.4	24.5	49.5

TABLE 3

Mean Maximum and Mean Minimum Temperatures

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley													
Mean maximum.......	37.8	37.5	50.3	61.2	72.8	79.7	84.6	81.7	76.4	64.3	52.1	39.5	61.5
Mean minimum.......	21.0	19.3	30.4	38.1	48.6	57.0	62.9	60.6	53.7	41.8	32.2	21.8	40.6
Frederick 1893–1944													
Mean maximum.......	40.5	42.1	53.6	65.3	76.9	84.2	88.6	86.1	80.0	67.8	54.4	42.7	65.2
Mean minimum.......	24.3	24.3	32.6	40.9	51.6	60.4	65.0	63.0	56.4	44.8	35.3	27.1	43.8
Mt. St. Mary's Seminary 1891–1944													
Mean maximum.......	39.3	40.3	51.2	62.3	73.5	80.9	85.4	83.0	76.9	65.5	52.9	41.7	62.7
Mean minimum.......	23.6	23.8	32.3	41.8	52.7	60.3	65.3	63.2	57.3	46.3	35.7	26.4	44.1
New Market—Monrovia													
Mean maximum.......	39.8	39.4	51.3	64.0	74.7	81.1	86.2	83.3	77.9	65.7	53.2	40.5	63.1
Mean minimum.......	24.4	22.3	32.3	41.3	51.6	59.4	64.8	62.8	56.1	45.5	35.5	26.0	43.5
State Sanatorium													
Mean maximum.......	38.8	39.9	49.7	61.2	72.3	79.7	83.8	81.4	75.1	64.0	51.4	40.2	61.5
Mean minimum.......	22.7	22.8	30.3	40.2	51.7	60.1	64.1	62.3	56.6	46.0	35.4	25.3	43.1
Taneytown													
Mean maximum.......	38.3	38.8	53.0	63.8	74.6	81.6	87.6	84.6	79.4	66.0	52.8	41.2	63.5
Mean minimum.......	22.6	19.9	32.0	39.8	49.9	58.4	63.5	62.1	55.5	43.2	33.2	24.3	42.0
Westminster													
Mean maximum.......	40.1	41.5	51.1	63.1	74.7	82.7	86.7	84.5	79.0	66.7	54.5	43.4	64.8
Mean minimum.......	23.8	23.8	31.5	40.3	50.8	59.5	63.1	61.7	56.6	44.4	35.4	27.1	43.2

TABLE 3—*Concluded*

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Woodstock 1892-1944													
Mean maximum	42.0	42.9	54.0	65.0	76.0	82.8	87.2	84.6	78.6	67.6	55.1	43.8	65.0
Mean minimum	23.4	23.3	31.8	40.3	50.7	59.4	63.7	62.3	55.7	43.5	34.1	25.9	42.8
Carroll and Frederick Counties													
Mean maximum	39.6	40.3	51.8	63.2	74.4	81.6	86.3	83.6	77.9	66.0	53.3	41.6	63.3
Mean minimum	23.2	22.4	31.6	40.3	51.0	59.3	64.0	62.2	56.0	44.4	34.6	25.5	42.9

not extreme within Carroll and Frederick Counties; marked temperature changes usually occur in the late autumn, in winter, and in the early spring.

Monthly mean temperatures increase from a minimum in January to a maximum in July.

Table 2 presents the highest, mean, and lowest monthly and annual temperatures for the stations within Carroll and Frederick Counties and for Woodstock.

Table 3 gives the average values of the highest afternoon temperature and of the lowest early morning temperature for each month and the year. The average daily range in temperature can be readily ascertained, being greatest in May and least in December.

Records of highest and lowest temperatures in Carroll and Frederick Counties are available only since 1890. The highest temperature recorded within this area was 109° on July 10, 1936 at Frederick and the lowest temperature recorded within this area was 23° below zero on January 15, 1912. The record of highest and lowest temperature for each month and year is given in tables 4, 5 and 6.

GROWING SEASON

The interval between the last killing frost in spring and the first killing frost in autumn is known as the "growing season." The length of the growing season varies from year to year. Since it is important to the farmer and to the amateur gardener to have some idea of the period of safety of crops, the table 7 will prove quite informative.

PRECIPITATION

Precipitation is caused by the condensation of invisible vapor in the higher altitudes by cooling.

Precipitation in the form of prolonged rains of autumn and spring, of prolonged rains or snows of winter, and of showers in summer, while a discomfort to us is also an important factor of climate. Precipitation provides the moisture in the soil for

TABLE 4

Highest and Lowest Temperatures

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley													
Highest	68	68	85	90	95	100	103	98	98	90	75	66	103
Lowest	−17	−23	−3	17	28	36	44	43	31	20	9	−12	−23
Frederick 1893–1944													
Highest	76	80	90	98	100	104	109	106	102	99	84	72	109
Lowest	−21	−12	0	13	30	38	42	39	28	22	4	−19	−21
Mt. St. Mary's Seminary 1891–1944													
Highest	74	77	89	93	93	99	102	104	98	96	77	75	104
Lowest	−23	−15	2	11	32	40	45	41	35	22	9	−5	−23
New Market—Monrovia													
Highest	71	70	89	96	97	99	105	100	96	88	83	69	105
Lowest	−13	−14	3	19	30	39	48	46	33	23	14	−12	−14
State Sanatorium													
Highest	72	74	86	91	93	97	102	104	96	91	76	68	104
Lowest	−12	−14	2	7	32	37	45	40	36	22	3	−9	−14
Taneytown													
Highest	70	69	87	94	99	99	105	101	100	91	77	66	105
Lowest	−22	−21	3	20	27	39	44	45	34	20	−1	−10	−22
Westminster													
Highest	74	79	83	94	99	102	103	104	98	95	78	73	104
Lowest	−14	−16	3	9	29	35	42	41	31	20	7	−10	−16
Woodstock 1892–1944													
Highest	75	80	90	95	96	101	105	103	101	95	81	72	105
Lowest	−18	−16	−4	12	27	34	44	41	31	18	3	−14	−18
Carroll and Frederick Counties													
Highest	76	80	90	98	100	104	109	106	102	99	84	75	109
Lowest	−23	−23	−4	7	27	34	42	39	28	20	−1	−19	−23

the growth of vegetation and crops, provides the water that feeds our wells, and provides the water that becomes stored by drainage in reservoirs behind dams for use by the population and the industries of large cities.

Precipitation is dependent upon the nearness of large bodies of water, which are the source of moisture carried by the winds from them over the land areas.

Precipitation varies from month to month, from season to season, and from year to year. There is little variation in the amount of precipitation that falls over

TABLE 5

Average Number of Days with Maximum Temperature 90°, or Above

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley				*	1	3	8	3	1	*			16
Frederick			*	*	2	8	14	10	4	*			38
Mt. St. Mary's Seminary				*	1	4	8	5	2	*			20
New Market—Monrovia				*	2	4	9	5	2				22
State Sanatorium				*	*	2	5	4	1	*			12
Taneytown				*	2	5	12	6	3	*			28
Westminster				*	2	6	11	8	3	*			30
Woodstock			*	*	2	6	11	7	2	*			28
Carroll and Frederick Counties			*	*	2	5	10	6	2	*			25

* Less than one day.

TABLE 6

Average Number of Days with Minimum Temperature 32° or Below

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley	27	26	19	8	1				*	6	16	27	130
Frederick	24	23	16	5	*				*	3	12	22	105
Mt. St. Mary's Seminary	25	23	16	4						2	11	22	103
New Market—Monrovia	25	24	19	5	*					*	12	24	109
State Sanatorium	21	19	16	5	*					2	10	19	92
Taneytown	26	25	17	6	*					5	16	26	121
Westminster	24	23	18	6	*				*	3	13	22	109
Woodstock	25	23	17	10	*				*	4	14	23	116
Carroll and Frederick Counties	25	23	17	6	*				*	3	13	23	110

Carroll and Frederick Counties. The average annual total of 43.89 inches over this area is greater by 2.25 inches than the average annual total for Maryland.

The amounts of precipitation are fairly well distributed during the months of the year, and suffice for agricultural purposes from March to September.

June, July, and August, the summer months, comprise the period of greatest monthly rainfall and November is the month of least monthly rainfall; the former occurring during the period of maximum crop growth and the latter after the close of the harvest season.

Summer droughts are rare. Droughts occurring in the other seasons of the year are of slight importance.

At times there is relief from the heat and lack of showers during the summer by the occurrence of a prolonged heavy rain, due to the passing of a storm area from the southern latitudes over Maryland.

Tables 8, 9, and 10 reveal the various phases of precipitation.

TABLE 7

Killing Frosts

Stations	Length of record	Spring			Autumn			Length of growing season		
		Latest date of last	Average date of last	Earliest date of last	Earliest date of first	Average date of first	Latest date of first	Longest	Average	Shortest
Bachman's Valley	22	May 22	Apr. 27	Apr. 7	Sept. 11	Oct. 10	Oct. 22	189	166	153
Frederick	43	May 16	Apr. 21	Mar. 18	Sept. 23	Oct. 17	Nov. 7	206	179	144
Mt. St. Mary's Seminary	47	May 12	Apr. 17	Mar. 31	Oct. 1	Oct. 25	Nov. 13	213	189	168
New Market—Monrovia	24	May 12	Apr. 23	Apr. 9	Sept. 22	Oct. 17	Nov. 9	202	177	150
State Sanatorium	36	May 12	Apr. 19	Apr. 2	Oct. 7	Oct. 24	Nov. 16	219	188	163
Taneytown	16	May 22	Apr. 21	Apr. 6	Oct. 3	Oct. 16	Nov. 3	207	178	140
Westminster	29	May 29	Apr. 23	Apr. 2	Sept. 29	Oct. 16	Nov. 7	196	176	151
Woodstock	52	May 29	Apr. 21	Mar. 22	Sept. 23	Oct. 16	Nov. 7	222	178	139

SNOWFALL

The fall of snow varies from flurries to heavy depths. Flurries occur as early as October and as late as May. The earliest snowfalls on record in autumn were October 30, 1925 and October 19, 1940, and the latest snowfalls on record in spring were April 15, 1923 and April 13, 1940. There was a "blizzard" snow in February 1899. The heaviest fall of snow on record occurred on Palm Sunday, March 29, 1942, when the depth ranged from 17 inches to 32 inches (tables 11 and 13).

FOGS

When water vapor or moisture in the atmosphere becomes so abundant as to present an interference to visibility, the phenomenon is known as 'fog.' Fog is formed above the earth's surface by the mixing of warm moist air with colder air; also by radiation. The most frequent fogs are ground, meadow, stream, and valley fogs, which dissipate within a few hours under the sun's influence after the break of

TABLE 8

Monthly and Annual Precipitation

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley													
Greatest......	6.08	8.22	9.36	7.02	15.32	13.87	14.70	12.04	7.87	10.72	8.43	11.18	78.72
Avarage......	3.52	4.10	4.31	4.14	4.95	4.80	5.04	4.80	3.68	3.70	3.08	4.20	50.32
Least.........	1.24	0.70	0.80	1.52	0.70	0.86	0.77	1.15	0.60	0.76	0.36	1.03	37.26
Frederick													
Greatest......	7.35	6.15	6.31	6.44	9.51	11.14	8.53	10.39	11.41	9.36	6.33	6.81	52.74
Average......	3.15	2.90	3.42	3.54	3.66	4.19	3.87	3.79	3.34	2.98	2.59	3.04	40.47
Least.........	0.57	0.79	0.49	0.70	1.01	0.74	0.22	0.33	0.45	0.19	0.57	0.55	19.84
Harney													
Greatest......	4.31	5.18	5.20	5.32	4.69	4.63	8.28	8.35	5.67	5.77	4.46	6.66	50.59
Average......	3.12	3.15	4.19	3.27	2.67	4.76	4.88	4.41	3.22	3.00	2.13	4.02	42.82
Least.........	2.32	0.90	2.84	1.10	0.82	2.69	2.74	1.74	1.39	1.10	0.85	2.00	35.35
Mt. St. Mary's Seminary													
Greatest......	7.37	7.02	8.75	10.82	11.74	11.74	13.26	12.19	14.18	9.85	11.00	7.49	65.29
Average......	3.27	3.06	4.04	3.63	4.13	4.19	4.19	4.16	3.64	3.62	3.25	3.16	44.34
Least.........	0.76	0.20	0.66	0.90	0.70	0.11	0.94	0.52	0.41	0.21	0.49	0.47	25.94
New Market—Monrovia													
Greatest......	6.57	5.99	6.03	7.38	9.64	12.08	9.48	12.22	10.64	7.97	10.10	7.46	58.51
Average......	3.08	3.00	3.48	3.23	3.56	4.30	4.35	4.49	3.46	2.90	3.03	3.08	41.96
Least.........	1.19	0.77	0.67	0.70	0.55	0.63	0.64	1.59	0.61	0.21	0.57	0.50	31.55
Schellman's Hills													
Greatest......	5.50	7.51	7.50	7.45	12.50	9.75	13.10	6.10	10.50	7.50	5.75	6.45	59.30
Average......	4.34	3.06	4.21	4.88	5.57	4.28	4.37	3.28	4.78	3.87	3.58	3.76	49.98
Least.........	3.50	0.48	0.95	1.55	1.50	1.50	1.25	0.75	1.75	1.50	1.75	1.05	41.80
State Sanatorium													
Greatest......	8.41	5.14	8.01	10.13	8.44	10.60	7.10	12.39	10.12	12.68	7.85	6.05	59.39
Average......	3.38	2.82	3.74	3.90	3.91	4.45	4.03	4.38	3.78	3.80	2.86	3.20	44.25
Least.........	1.51	0.70	1.13	0.88	0.91	1.46	0.31	0.66	0.56	0.12	0.07	1.05	26.62
Taneytown													
Greatest......	4.48	5.57	6.31	6.08	8.24	6.67	10.20	11.29	8.00	6.00	6.04	5.75	51.63
Average......	2.68	3.37	3.62	3.11	3.60	3.60	4.29	4.19	3.38	2.70	2.81	3.19	40.54
Least.........	1.00	0.91	0.47	1.07	0.73	1.18	0.92	0.58	1.09	0.20	0.61	0.49	28.30
Westminster													
Greatest......	6.45	6.46	6.80	7.12	8.53	9.39	8.00	11.83	9.92	8.71	6.71	8.50	57.73
Average......	3.16	2.99	3.87	3.54	3.61	3.99	3.77	4.67	3.84	3.44	2.88	3.17	42.95
Least........	1.18	0.90	1.35	1.00	0.90	0.86	0.68	1.45	0.69	0.20	0.52	1.00	27.16
Woodstock													
Greatest......	7.75	6.69	7.65	7.21	10.34	8.90	10.00	11.53	13.58	10.23	6.54	9.29	57.77
Average......	3.27	3.02	3.61	3.31	3.61	3.76	3.79	4.18	3.56	3.16	2.76	3.01	41.04
Least.........	0.77	0.53	0.46	0.86	0.57	0.56	0.25	0.50	0.23	0.18	0.36	0.63	20.07

day. The morning 'mist' is also a fog. The more noticeable fogs are the dense or heavy ones of the cold season of the year from autumn to spring, which interfere with movements of marine, land, and air traffic. They form in the wake of a cool or

TABLE 9

Greatest 24-Hour Precipitation

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley	2.70	3.42	3.98	2.60	7.93	2.99	2.45	3.90	4.80	3.45	3.28	2.86	7.93
Frederick	2.54	2.50	1.76	2.75	4.56	4.22	3.29	4.19	4.26	3.53	3.61	2.32	4.56
Harney	1.62	1.87	2.25	3.22	1.80	2.38	2.77	4.40	2.07	2.35	1.42	2.26	4.40
Mt. St. Mary's Seminary	2.50	2.65	3.00	3.72	4.18	3.20	3.50	4.20	4.60	3.60	3.89	3.13	4.60
New Market—Monrovia	2.05	2.48	2.49	2.18	3.47	5.01	2.85	8.66	2.46	2.02	1.98	2.25	8.66
State Sanatorium	2.70	2.90	4.05	3.80	3.59	3.50	3.65	4.10	4.10	4.00	2.71	3.35	4.10
Taneytown	1.57	1.30	1.83	2.27	3.35	1.91	2.10	5.00	2.45	2.40	3.47	1.70	5.00
Westminster	2.25	3.80	2.20	2.56	2.40	2.82	2.82	4.60	4.48	3.10	4.36	1.95	4.60
Woodstock	2.87	2.64	2.30	3.18	3.41	3.06	2.72	5.03	4.10	3.60	3.47	2.90	5.03
Carroll and Frederick Counties	2.87	3.80	4.05	3.80	7.93	5.01	3.65	8.66	4.80	4.00	4.36	3.35	8.66

TABLE 10

Average Number of Days with Precipitation (0.01 Inch or More)

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley	8	7	8	7	9	9	8	7	5	6	5	7	86
Frederick	10	9	11	11	11	11	11	11	8	9	8	10	120
Harney	7	6	8	6	6	9	9	7	6	5	5	7	81
Mt. St. Mary's Seminary	9	9	10	10	11	10	10	9	8	8	7	8	109
New Market—Monrovia	10	8	10	9	10	11	10	10	7	8	7	9	109
State Sanatorium	12	12	12	13	14	14	12	12	10	11	10	12	144
Taneytown	8	9	10	10	10	10	10	10	7	8	8	9	109
Westminster	9	9	10	10	10	10	10	10	8	8	8	9	111
Woodstock	9	9	10	9	10	10	10	10	7	8	8	9	109
Carroll and Frederick Counties	9	9	10	9	10	10	10	10	7	8	7	9	108

cold period, when the wind shifts into easterly to southerly and draws inland the warmer moist air overlying the ocean. This air is moist, and is warmer than the air overlying the cold land surface. These fogs may endure from several hours to a day or longer. A necessary factor to the formation of fog is a very light air movement, or a calm.

Since the fog records for Carroll and Frederick Counties are incomplete the averages of these data are presented for Baltimore, Maryland, 1891–1944 (table 14).

TABLE 11

Average Monthly and Annual Snowfall

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley	8.3	8.7	6.1	1.5	T					T	2.6	6.1	33.3
Frederick	7.5	7.8	5.2	0.7	T					0.1	0.7	4.4	26.4
Harney	10.9	7.6	7.3	0.1	T					T	0.2	4.5	30.6
Mt. St. Mary's Seminary	8.8	8.9	7.1	1.3	T					0.1	0.9	5.0	32.1
New Market—Monrovia	7.0	8.0	4.7	0.9	T					T	1.1	5.2	26.9
State Sanatorium	9.6	8.4	7.9	1.6	T					0.2	1.1	5.4	34.2
Taneytown	7.0	10.6	4.9	1.1	T					T	1.4	3.9	28.9
Westminster	7.8	8.2	7.6	0.8	T					0.2	0.9	4.0	29.5
Woodstock	6.5	6.3	4.7	0.7	T					0.1	0.6	3.7	22.6
Carroll and Frederick Counties	8.2	8.3	6.2	1.1	T					0.1	1.1	4.7	29.7

TABLE 12

Greatest 24-Hour Snowfall

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley	12.0	11.0	14.0	7.5	T					0.2	7.0	9.0	14.0
Frederick	13.0	12.0	17.0	9.8	T					3.2	10.0	9.0	17.0
Harney	7.0	10.0	14.0	0.5	T					T	0.5	6.0	14.0
Mt. St. Mary's Seminary	13.0	16.0	21.0	11.0	T					3.5	8.0	10.5	21.0
New Market—Monrovia	9.5	12.0	12.0	3.0	T					T	5.0	9.0	12.0
State Sanatorium	11.0	14.0	30.0	9.0	T					4.5	8.0	8.0	30.0
Taneytown	11.0	10.2	15.0	15.0	T					T	7.0	10.0	15.0
Westminster	12.0	11.0	32.0	10.0	T					3.1	8.0	9.0	32.0
Woodstock	14.0	11.0	24.0	7.6	T					2.5	8.0	10.0	24.0
Carroll and Frederick Counties	14.0	16.0	32.0	15.0	T					4.5	10.0	10.5	32.0

HUMIDITY

The atmosphere enveloping the earth is constantly receiving moisture from land and water surfaces and giving it back in the form of rain, sleet, snow, hail, fog, dew, and frost. This moisture varies with temperature, as a cubic foot of air at 50° when saturated at sea-level pressure can hold about 4 grains of water vapor; at 70°, 8 grains; and at 100° about 20 grains. The specific heat of water is so much higher than that of air that the moisture present tends to temper the temperature and reduce the extremes. Humidity is increased by moisture bearing winds from all

TABLE 13

Average Number of Days with Snow (0.1 Inch or More)

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley........	3	3	2	1						*	1	2	12
Frederick.......	4	3	2	1						*	1	2	13
Harney.........	3	3	2	*							1	2	11
Mt. St. Mary's Seminary.....	5	5	2	1						*	1	2	16
New Market—Monrovia.....	3	3	2	1							1	2	12
State Sanatorium	4	4	3	1						*	1	3	16
Taneytown......	4	4	2	*							1	2	14
Westminster.....	3	3	2	1						*	1	2	12
Woodstock......	3	3	2	*						*	1	2	11
Carroll and Frederick Counties.	4	4	2	1						*	1	2	14

* Less than one day.

TABLE 14

Average Monthly and Annual Number of Days with Fog

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Light..........	11	8	8	6	6	4	4	5	8	11	9	10	90
Heavy..........	2	2	2	1	*	*	*	*	1	1	2	3	14

* Less than one day.

TABLE 15

Average Monthly and Annual Relative Humidity at Baltimore, Maryland, 1888–1944

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
70	67	65	62	64	67	68	71	72	70	68	68	68

bodies of water. Water vapor adds much to personal discomfort. It causes oppressive muggy weather when the temperature is high and raw penetrating cold when the temperature is low. Humidity varies from hour to hour, from day to day, and from month to month. The diurnal variation has its maximum in the early morning hours and its minimum during the early afternoon. The average monthly humidity varies from the least in April to the greatest in September. There are no

TABLE 16

Average Number of Clear, Partly Cloudy, and Cloudy Days

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley													
Clear	17	14	17	17	17	20	22	21	22	21	20	19	227
Partly cloudy	6	6	6	7	8	6	6	6	4	4	4	5	68
Cloudy	8	8	8	6	6	4	3	4	4	6	6	7	70
Frederick													
Clear	13	12	14	14	15	15	16	16	17	17	14	13	176
Partly cloudy	6	7	8	7	9	9	10	9	7	7	8	7	94
Cloudy	12	9	9	9	7	6	5	6	6	7	8	11	95
Harney													
Clear	11	13	13	12	14	11	12	12	16	16	12	13	155
Partly cloudy	11	9	9	12	11	13	16	14	9	10	13	10	137
Cloudy	9	6	9	6	6	6	3	5	5	5	5	8	73
Mt. St. Mary's Seminary													
Clear	12	12	14	13	14	15	15	15	17	17	14	13	171
Partly cloudy	7	7	7	8	9	9	11	9	7	7	8	7	96
Cloudy	12	9	10	9	8	6	5	7	6	7	8	11	98
New Market—Monrovia													
Clear	11	11	12	11	12	12	15	14	15	16	12	12	153
Partly cloudy	8	6	8	11	11	11	11	10	9	6	8	8	107
Cloudy	12	11	11	8	8	7	5	7	6	9	10	11	105
State Sanatorium													
Clear	12	13	15	14	16	15	16	16	16	17	13	13	176
Partly cloudy	7	6	7	7	7	9	10	8	7	6	8	6	88
Cloudy	12	9	9	9	8	6	5	7	7	8	9	12	101
Taneytown													
Clear	13	13	14	14	16	17	18	15	17	17	14	13	181
Partly cloudy	8	6	7	8	9	8	8	10	8	6	8	7	93
Cloudy	10	9	10	8	6	5	5	6	5	8	8	11	91
Westminster													
Clear	13	12	14	14	14	16	17	16	16	16	13	12	173
Partly cloudy	7	7	8	7	10	9	10	9	8	7	8	8	98
Cloudy	11	9	9	9	7	5	4	6	6	8	9	11	94
Woodstock													
Clear	11	12	14	13	14	14	14	15	16	16	13	13	165
Partly cloudy	8	6	8	7	9	10	10	9	7	7	7	7	95
Cloudy	12	10	9	10	8	6	7	7	7	8	10	11	105
Carroll and Frederick Counties													
Clear	12	12	14	14	15	15	16	16	17	17	14	14	176
Partly cloudy	8	7	8	8	9	9	10	9	7	7	8	7	97
Cloudy	11	9	9	8	7	6	5	6	6	7	8	10	92

humidity values for Carroll and Frederick Counties, so we present the values for Baltimore, the nearest point of observation and record (table 15).

CLOUDINESS

Cloudiness is based upon an estimate of the amount of the sky covered by clouds during the day from sunrise to sunset. When the estimate of clouds for the day is not more than 0.3 of the sky, the day is classified as 'clear'; when the estimate of clouds for the day covers from 0.4 to 0.7 of the sky, the day is classified as 'partly cloudy'; and when the estimate of clouds covers from 0.8 to overcast, the day is classified as 'cloudy.' The averages of these data are presented in table 16.

SUNSHINE

Carroll and Frederick Counties lie within an area of abundant sunshine. Sunshine varies from day to day, from month to month, and from year to year. The

TABLE 17

Percentage of Possible Sunshine

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
49	55	58	59	61	64	66	64	65	63	55	49	59

TABLE 18

Average Monthly and Annual Hourly Wind Velocities, Baltimore, Maryland

Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1872–1944	8.1	8.5	9.0	8.8	8.1	7.8	7.4	7.2	7.3	7.6	7.9	7.9	8.0

winter is the period of least sunshine and June to September is the period of greatest sunshine. There are no records of sunshine in Carroll and Frederick Counties, so the averges of the records of sunshine at Baltimore, Maryland, 1893–1944, are presented in table 17.

WINDS

The velocity and direction of the winds vary from hour to hour. The minimum velocity of the wind is in the morning before dawn, after which it increases rapidly with the increase in temperature to a maximum in the mid-afternoon, and then diminishes rapidly at first with decrease in temperature and then slowly to the early morning minimum. The annual variation does not conform to the diurnal one, the average velocity being least in August and greatest in March.

There are no automatic records of the velocity of the wind in Carroll and Frederick Counties. The wind velocity data in miles for Baltimore, Maryland, are presented in table 18.

The prevailing direction of the winds over Carroll and Frederick Counties is deduced by eye observation, since there are no automatic records. The prevailing direction is from the northwest from October to April, from the southwest from May to September, and from the northwest for the year. The prevailing direction of the

TABLE 19

Prevailing Wind Direction

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bachman's Valley	NW	NW	NW	NW	SW	SW	SW	SW	SW	NW	NW	NW	NW
Frederick	NW	NW	NW	NW	SW	SW	SW	SW	SE	NW	NW	NW	NW
Mt. St. Mary's Seminary	W	NW	NW	W	SW	SW	SW	SW	W	NW	NW	W	W
New Market—Monrovia	NW	NW	NW	NW	NW	NW	SW	S	S	NW	NW	NW	NW
State Sanatorium	W	NW	NW	W	W	NW	SW	SW	SW	W	NW	NW	NW
Taneytown	NW	NW	NW	NW	SW	SW	SE	SW	SE	W	NW	NW	NW
Westminster	NW	NW	NW	SW	SW	SW	SW	SW	SW	SW	NW	NW	SW
Woodstock	NW	NW	NW	NW	NW	SW	SW	NW	NW	NW	NW	NW	NW
Carroll and Frederick Counties	NW	NW	NW	NW	SW	SW	SW	SW	SW	NW	NW	NW	NW

CLIMATOLOGICAL SUMMARY OF CARROLL AND FREDERICK COUNTIES

	Temperature							Precipitation						
											Snowfall			
	Mean	Mean maximum	Mean minimum	Highest	Lowest	No. of days 90°, or above	No. of days 32°, or below	Average	Greatest in 24 hours	No. of days with 0.01 inch or more	Average	Greatest in 24 hours	No. of days with 0.1 inch or more	Prevailing wind direction
January	31.3	39.6	23.2	76	−23	0	25	3.30	2.87	9	8.2	14.0	4	NW
February	31.5	40.3	22.4	80	−23	0	23	3.15	3.80	9	8.3	16.0	4	NW
March	40.9	51.8	31.6	90	−4	*	17	3.85	4.05	10	6.2	32.0	2	NW
April	51.3	63.2	40.3	98	7	*	6	3.66	3.80	9	1.1	15,0	1	NW
May	62.4	74.4	51.0	100	27	2	*	3.93	7.93	10	T.	T.	0	SW
June	70.3	81.6	59.3	104	34	5	0	4.23	5.01	10	0.0	0.0	0	SW
July	74.8	86.3	64.0	109	42	10	0	4.26	3.65	10	0.0	0.0	0	SW
August	72.5	83.6	62.2	106	39	6	0	4.24	8.66	10	0.0	0.0	0	SW
September	66.2	77.9	56.0	102	28	2	*	3.67	4.80	7	0.0	0.0	0	SW
October	54.6	66.0	44.4	99	20	*	3	3.32	4.00	8	0.1	4.5	*	NW
November	43.5	53.3	34.6	84	−1	0	13	2.90	4.36	7	1.1	10.0	1	NW
December	33.4	41.6	25.5	75	−19	0	23	3.38	3.35	9	4.7	10.5	2	NW
Annual	52.7	63.3	42.9	109	−23	25	110	43.89	8.66	108	29.7	32.0	14	NW

* Less than one day.

wind for any locality can be realized by observing the 'bend' or the 'lean' of the trees (table 19).

MAGNETIC DECLINATION IN CARROLL AND FREDERICK COUNTIES

PREPARED UNDER THE SUPERVISION OF

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Importance of a Knowledge of the Earth's Magnetism

The human race managed without the implements of reliable navigation for untold ages, including most of the span that is covered by written records.

Whenever the heavens were obscured, any vessel on the open sea was precariously dependent upon her master's success in reading the winds and waves. The introduction of the compass in late medieval times gave reliable directions, regardless of wind and weather. It is scarcely an accident that the age of discovery closely followed the development of the compass. The safe return of Columbus from his epoch-making voyage gave impetus to a new spirit of exploration that finally culminated in the mapping of nearly the whole surface of the globe.

Although centuries have passed since the compass was introduced, it still holds an important place in navigation, and is the simplest and cheapest direction finder on land and sea and in the air.

Since there are few places where the needle points to true north and since the direction is continually changing, the user needs correct information regarding both the direction of the pointing and its changes.

Small vessels and boats depend entirely on the magnetic compass. Larger vessels and submarines are usually equipped with the gyro compass; but since it has moving parts which must be kept in good order, one or more magnetic compasses are kept in reserve.

Air navigation has relied basically on the earth's magnetism for direction finding. Several special types of compass, the more elaborate employing the principle of the earth inductor and other devices, have been developed. Provision is made at many air fields for determination of the errors in the compass pointings, and this requires accurate knowledge of the earth's magnetic field at the place of testing.

The compass was one of the most important surveying instruments in the early centuries of the modern era. It is not, however, an instrument of precision; results of great accuracy are not to be expected in compass surveys, and the use of a compass as a surveying instrument should be avoided where circumstances permit (especially in areas where local control surveys have been made), or where pronounced local magnetic disturbance renders the compass unreliable. On the other hand, it has the advantage of speed and simplicity, and is useful for retracing lines of old surveys originally established by compass, and for surveys where great accuracy is not required, particularly in wooded areas. Nearly all the early land surveys of the United

States were made by compass. Transfers of property often require identification of boundaries established by compass, so that knowledge of the changes in magnetic directions becomes important. The extension of the magnetic work of the United States Coast and Geodetic Survey to cover the interior of the country was partly due to this need.

The upper atmosphere is ionized by solar radiations and thereby becomes electrically conducting. The ionization is closely associated with the changes in the earth's magnetism, including those known as magnetic storms. Since the ionization is intimately connected with radio communication and with some of its disturbances, the earth's magnetism has a definite relation to radio communication.

Natural electric currents known as earth currents occur in the ground; they are usually small but at times are strong enough to interfere with wire and cable communication and even with transmission of electrical power. The study of these currents involves directly the changes in the earth's magnetism.

The study of the highly penetrating radiation known as cosmic rays has shown that these rays are affected by the earth's magnetic field and its fluctuations.

With so many matters of everyday occurrence directly or indirectly affected by the earth's magnetism, it is very important that we should find out all we can about it—how it is distributed over the earth's surface; how it changes from hour to hour and from year to year; how it originated and what causes it to change; and how it is related to earth currents, atmospheric electricity, solar activity, and other allied phenomena.

GENERAL INFORMATION

The Magnetic Elements

The earth acts like a great spherical magnet in that it is surrounded by a magnetic field, and the measurement of the earth's magnetism at any place consists in determining the direction and intensity of that field.

A magnet suspended in such a way as to be free to turn about its center of gravity would take a position with its magnetic axis directed along the lines of force of the earth's magnetic field. It is practically impossible to suspend a magnet in that way, but we may determine the direction of the earth's magnetic field by means of two magnets, one constrained to turn about a vertical axis, giving the direction in the horizontal plane (compass needle) and the other constrained to turn about a horizontal axis, giving the direction in the vertical plane (dip needle).

The *magnetic meridian* at any place is the vertical plane fixed by the direction of the lines of force at that place. The angle it makes with the plane of the astronomic or true meridian is called the *magnetic declination*,[1] D, and is considered east or west according as the north end of the needle points east or west of true north.

The *dip* or *inclination*, I, is the angle which the lines of force make with the plane of the horizon.

It is possible to measure the *total intensity*, F, of the earth's magnetic field, but it is usually more convenient to measure its *horizontal component*, H. These three

[1] Known to some as the *variation of the compass.*

quantities, declination, dip, and horizontal intensity, are usually spoken of as the *magnetic elements*, and from them the total intensity and its component in any direction may be computed by simple formulas.

Distribution

The earth's magnetism is different in different parts of the earth, and its distribution over the surface is so irregular that observations must be made at a great many places in order to get a satisfactory picture of the phenomenon. There are, however, certain elements of regularity. There are two points, defined as the *magnetic poles*, at which the dip needle stands vertical and the earth's magnetic field is directed vertically, so that the horizontal intensity is zero and the compass needle cannot be used to determine direction. The north magnetic pole is approximately in latitude 71° N. and longitude 96° W., and the south magnetic pole in latitude 73° S. and longitude 156° E.

Going away from the magnetic poles the dip decreases and the horizontal intensity increases until the *magnetic equator* is reached. There the dip is zero and the magnetic field is exactly horizontal. The magnetic equator is south of the geographic equator in South America and north of it in Africa and Asia. The total intensity at the magnetic poles is roughly twice as great as at the magnetic equator.

The Compass and the Magnetic Poles

There is a widespread fallacious idea that the compass is controlled by an attractive force centering in one of the magnetic poles. This has even led to the mistaken notion that the direction of the compass needle would reverse in crossing the equatorial regions. Actually, the direction and intensity of the magnetic field at any given point are probably controlled (or at least greatly influenced) by the nearest portions of the earth's active magnetic interior. While the compass needle points in a northerly direction for most of the surface of the earth, as a rule it does not point exactly toward either the magnetic pole or the geographic pole. In the United States it points 22° west of true north in northeastern Maine and 24° east of true north in northwestern Washington. Along the ninety-sixth meridian, where the needle would point true north if it were directed toward the magnetic pole, it actually points 9° or 10° east of true north. The agonic line, or line of zero declination, is a very crooked one, crossing the country from the vicinity of Marquette, Mich., to Savannah, Ga. The compass needle is not perceptibly drawn toward the magnetic pole, or any other special point on the earth's surface. The effect of the earth's field on a compass needle or other magnetized object is primarily that of a turning force on each of the innumerable tiny magnets composing the object, rather than an attraction. When the needle is allowed to respond to this turning force, it simply indicates how the earth's field is oriented at the observer's location.

It is true that, for instance, an airplane which made a flight so as to travel always in the direction in which the north-seeking end of the compass needle points would eventually reach the vicinity of the earth's north magnetic pole in northern Canada, though its course would deviate considerably from the great-circle path. This result does not conflict with the previous paragraphs but shows that the earth's magnetism has a measure of world-wide coordination and (in conjunction with other observed facts) indicates that the earth behaves somewhat like a spherical magnet, as mentioned above. Now, a spherical magnet does not have "poles" in the narrow technical sense (i.e., points at which there can be imagined to be centers of attraction in such a way as to explain observed facts). If such poles are postulated as a device for describing the magnetic field of a uniformly magnetized sphere, it is found that they would both have to be at practically the same point, namely, the center of the sphere. Expressed in another way, the external magnetic field of such a sphere is the same as that which would surround an inert sphere having a very small and powerful bar magnet at its center. The earth's magnetic poles, then, are not centers of attraction but simply the localities at which the field happens to be perpendicular to the earth's surface. It is quite likely that there would be much less popular interest in the location of the magnetic poles if it were thoroughly understood that their positions do not determine the direction taken by the compass.

In most of the southern hemisphere the same end of the compass needle points north as in most of the northern hemisphere. The amount of the declination cannot be determined through a knowledge of the location of the magnetic poles, but can be mapped only by making actual observations at widely distributed places over the region in question.

There is another widespread misconception associated with the false concept of an attractive center, namely, the idea that secular changes are to be ascribed to a sort of precession or migration of the magnetic poles. This is a very old notion, dating back almost as far as the first realization of the great magnitude of secular change. As recently as 50 years ago it was given some credence despite the obvious difficulties of reconciling the conflicting directions and rates of change derived from records at different parts of the world. It is now known, however, that the secular changes are too complex to be accounted for in this way. Furthermore they are in most regions too great to be reconciled on this basis with the known facts concerning the position of the magnetic north pole, which has shifted very little during the century since it was first located.

How Magnetic Observations are Made.

Since the declination is the angle between the true and magnetic meridians, both of these must be determined. In a magnetic survey the true meridian is determined by observations of the sun or stars with a theodolite, unless the observations are being made near a triangulation station at which azimuths of objects visible from the ground are available. In the most precise surveys, the magnetic meridian is determined with a magnetometer. This instrument contains a suspended hollow magnet, closed at one end by a collimating lens and at the other by a plane glass on which there are a horizontal line and a central vertical line situated at the principal focus of the collimating lens. The magnet is suspended by a silk fiber or very fine phosphor-bronze or gold ribbon in a wooden box, which shields it from currents of air and from rapid changes of temperature. A telescope is attached to the box in such a way that it may be pointed on a distant object or (through the magnet lens) on the vertical line of the magnet. The box is mounted on a base with graduated horizontal circle, so that the angle between a distant object and the magnetic meridian defined by the magnet can be measured. If the angle between the same distant object and the true meridian has been determined by astronomical observations, the magnetic declination is found directly by taking the difference between the two angles, and applying the index correction of the instrument.

The methods of observing horizontal intensity and dip are described in the Coast and Geodetic Survey's Serial 166, and brief descriptions of the methods are given in Serials 618 and 663.

MAGNETIC SURVEY OF THE UNITED STATES

Scope of the Survey

The United States Coast and Geodetic Survey has made magnetic observations at about 7,000 places in the United States, including nearly every county seat. Each place where such observations have been made is called a ***magnetic station.*** The station is usually marked by a stone or concrete post with a bronze disk set in the top. Distances are measured to nearby objects, and the azimuths or true bearings of a number of distant objects are determined. With the aid of this information it is usually possible to relocate the point of observation and determine the true meridian without further astronomical observations.

Condition and Location of Stations

In planning the magnetic survey of the United States, an effort was made to place the stations where they could readily be reached by local surveyors and engineers, as it was recognized that the stations would be used by many of them for the purpose of testing their compasses. Accordingly most of the stations are in or near county seats. In the selection of a station site, care was taken to avoid places where there were indications of natural or artificial local disturbances. In many cases, however, industrial developments incident to increase in population have put an end to their usefulness.

Repeat Observations

Observations have been repeated about every 5 years at selected stations distributed over the whole country, to keep track of the changes taking place in the earth's magnetism with lapse of time.

Magnetic Observatories

For more detailed information regarding these changes, the Coast and Geodetic Survey has maintained magnetic observatories at intervals since 1860 and continuously since 1900. Those operated at present are near Cheltenham, Prince Georges County, Maryland; Honolulu, Territory of Hawaii; San Juan, Puerto Rico; Sitka, Alaska; and Tucson, Arizona. Continuous photographic records secured at these observatories show the fluctuations in direction and intensity of the magnetic field.

MAGNETIC SURVEY OF MARYLAND

The original magnetic survey of Maryland was made during the years 1896–1900. In 1896, the Maryland Geological Survey employed the late Dr. L. A. Bauer to make a magnetic survey of the State. By prodigious effort he completed a fairly adequate survey of Maryland in three months. The Maryland Geological Survey continued to employ him in 1897 and 1898, and he occupied numerous additional stations. In May 1899, Bauer entered the service of the Coast and Geodetic Survey, becoming chief of its newly organized Division of Terrestrial Magnetism, now known as the Division of Geomagnetism and Seismology. The survey of Maryland was continued by the Coast and Geodetic Survey in 1899 and 1900. The results of this survey were published in two reports described at the end of this chapter.

Most of the magnetic observations by the Coast and Geodetic Survey in Maryland between 1901 and 1938 were made at selected "repeat stations." In 1938 and 1939, an observer was attached to each of five triangulation parties of the Coast and Geodetic Survey, who made magnetic observations with a compass declinometer at or near many of the triangulation stations. One of these parties worked for several months in Carroll and Frederick Counties.

CHANGES OF THE EARTH'S MAGNETISM

The earth's magnetic field is always changing. It is desirable to divide the change into several parts. The parts discussed in this chapter are the daily variation, irregular disturbances, magnetic storms, secular changes, annual change, and annual variation.

Daily Variation

There is usually a systematic departure of the declination from its daily mean value, which occurs day after day, the amount of departure depending upon the time of day, the season, the magnetic latitude, and other factors. This systematic, daily departure from the mean value for the day is called *daily variation.*

In northern latitudes, the daily variation of declination is characterized by an easterly motion of the north end of the needle in the morning, with an easterly extreme about 8 or 9 a.m., local time; then a westerly motion, with a westerly extreme about 1 or 2 p.m.; then an easterly motion for 4 or 5 hours. From dusk to the early morning there is little change.

The daily range is greater in summer than in winter, and greater toward the magnetic pole than toward the equator. It should be noted, however, that for the winter months the daily range is about the same at Sitka as at Honolulu, and less than at the intermediate stations; the time that the sun is above the horizon (only about 8 hours at Sitka as compared with 11 hours at Honolulu) is one of the controlling factors.

In the Southern Hemisphere conditions are reversed. The westerly extreme occurs in the morning and the easterly extreme in the afternoon. The greatest amplitude occurs in the southern summer; i.e., in December.

A portion of the Tropics constitutes a transition belt, in which the northern type of daily variation predominates in June and the southern type in December.

The practical significance of the daily variation of declination may be seen from the following example: In the United States in summer the north end of the compass needle points on the average about 10′ more to the west at 1 p.m. than it does at 8 a.m. Consequently a line 1,000 feet long run by compass at the time of the westerly extreme would have its terminal point 2.9 feet to the left of a line of the same length from the same starting point run at the time of the easterly extreme.

TABLE I

Average Daily Variation of Magnetic Declination in Carroll and Frederick Counties

This table shows the average daily variation for 10 quiet days of each month for the years 1918–28. A plus sign indicates that west declination is greater than the mean for the day. For individual quiet days, the range may be more or less, and the extremes may come at different times. The 75th meridian time is Eastern Standard Time.

75th Meridian Time	Jan., Feb., Nov., Dec.	Mar., Apr., Sept., Oct.	May, June, July, Aug.	75th Meridian Time	Jan., Feb. Nov., Dec.	Mar., Apr., Sept., Oct.	May, June, July, Aug.
	′	′	′		′	′	′
1 a.m.	+0.1	−0.4	−0.2	1 p.m.	+3.0	+4.6	+5.5
2 a.m.	+0.2	−0.5	−0.3	2 p.m.	+3.2	+4.8	+5.5
3 a.m.	+0.2	−0.6	−0.4	3 p.m.	+2.7	+4.0	+4.4
4 a.m.	−0.1	−0.9	−0.9	4 p.m.	+1.6	+2.4	+2.7
5 a.m.	−0.4	−1.3	−1.9	5 p.m.	+0.8	+1.2	+1.2
6 a.m.	−0.8	−2.2	−3.9	6 p.m.	+0.2	+0.7	+0.3
7 a.m.	−1.1	−3.4	−5.5	7 p.m.	−0.2	+0.4	+0.1
8 a.m.	−2.3	−4.7	−6.0	8 p.m.	−0.4	0.0	+0.4
9 a.m.	−3.1	−4.1	−4.9	9 p.m.	−0.6	−0.2	+0.2
10 a.m.	−2.7	−2.6	−1.8	10 p.m.	−0.6	−0.4	0.0
11 a.m.	−0.7	+0.6	+1.8	11 p.m.	−0.4	−0.2	−0.2
Noon	+1.6	+3.3	+4.5	Midnight	−0.2	−0.4	−0.2

The amplitude of the daily variation is not predictable for any one day, although its mean amplitude for a month or more will usually conform fairly closely to previous experience, provided the days of unusual disturbance are rejected from the mean.

Table I shows the average daily variation of the magnetic declination in Carroll and Frederick Counties, based on the records of the Cheltenham Magnetic Observatory. For individual undisturbed days, the departures from the daily mean may be more or less than those shown; and the extremes may come earlier or later. If a more accurate correction is required, it may be obtained from the U. S. Coast and Geodetic Survey, Washington 25, D. C., if the place, date, and time are given.

Irregular Disturbance and Magnetic Storms

The daily variation is a phenomenon of local time; that is, the cycle of changes is not simultaneous for different longitudes, but each phase of the cycle in turn traverses the globe from east to west, leading or lagging the sun by a constant time interval.

The magnetic elements are, in addition, usually disturbed to some extent by irregular fluctuations, some of which affect wide regions of the earth's surface simultaneously. These changes, as well as the daily variation, are evidences of complex changes in the distribution of electric space-currents in the ionized regions of the earth's outer atmosphere.

There is a well-established statistical connection between solar phenomena and the irregular magnetic disturbances, which fluctuate considerably in intensity from day to day. Ordinarily they are (except in high latitudes) a minor feature of the record, but occasionally they become suddenly violent and prolonged, constituting a *magnetic storm.* A magnetic storm may last many hours (sometimes several days) and the more severe ones are known to extend from pole to pole over both the light and dark sides of the earth. They are directly associated with the appearance of aurora and with other phenomena of the ionosphere. Studies have revealed a remarkable recurrence phenomenon with a period of approximately 27 days, corresponding to the rotation of the sun. The sequence of quiet and disturbed days does not form a permanent cyclical pattern, since a new disturbance may occur at any time or an old one die out. However, the trend is for any marked disturbance to reappear in several successive months before it permanently disappears.

Secular and Annual Change

At any particular site, the average value of a magnetic element for one year may differ from that for the next. In general, the change progresses in one direction for many years and is known as the *secular change.* The amount of secular change in one year is known as the *annual change.*

As is illustrated by Table IV, the change from year to year is not uniform, nor does it go on indefinitely in one direction. At some stations, where declination results are available for 200 years or more, two turning points are indicated; for example, the declination at London was 11° East in 1580 and 24° West in 1810, a change of 35° in 230 years. Tables showing the secular change in the United States are given in Serials 602 and 664 of the Coast and Geodetic Survey. Table III shows the secular change of declination in Carroll and Frederick Counties.

Despite earlier attempts to predict secular change, it is now recognized that because of the many unknown factors involved there is as yet no basis for such predictions. Secular change can be determined *only* by direct observation. When an estimate must be made for some future date, the best that can be done is to assume that the rate of change in the future will be the same as that observed in the recent past. However, every now and then the rate undergoes a considerable alteration within a short interval, as is illustrated by comparison of the rates before and after 1933 in Table IV. Hence, no attempt should be made to predict the declination for more than a few years in advance.

Annual Variation

When the average monthly values of an element are corrected for the trend of secular change, it is found that there is a small systematic seasonal effect. For example, in Maryland the west declination decreases slightly in summer, and increases in winter. This phenomenon is called *annual variation.* It is quite small, of the order of one minute of arc or less, and is different in different parts of the United States.

MAGNETIC CHARTS

The results of magnetic observations may be listed in tabular form, but from these the field can scarcely be visualized. Accordingly, magnetic charts are prepared, which give convenient representation of the different features. On the charts, *isomagnetic lines* are drawn through places having the same value of some element. The names of these lines and of the charts which portray them are: declination—*isogonic*; dip or inclination—*isoclinic*; and intensity (e.g., horizontal, vertical, or total intensity)—*isodynamic.* For most parts of the earth, the data are more complete for the isogonic charts than forother charts. From isogonic charts are derived data shown on every mariner's chart and every aeronautical chart.

Since the field changes from year to year, a chart must be prepared as of a given date or "epoch."

Available Data

In some countries, the observations of magnetic declination are quite numerous, whereas in a few remote regions none at all have been made. For the United States, observations at about 7000 points are available, with a smaller number for the other magnetic elements. The values of declination available in Carroll and Frederick Counties are shown in Table II.

Construction of Charts

The method of using observed data to prepare charts varies with the number and spacing of the observations. Usually, the more observations, the greater the irregularity they reveal. In general, the available values of the desired element are plotted on a base map and isomagnetic lines are drawn to conform best with them. It might seem desirable to draw the isomagnetic lines so that all greater values would be on one side and all lesser ones on the other. This, while always possible, is not usually desirable, since the principal purpose of the chart is to indicate the most probable values at places where no observations have been made.

Perhaps a better picture of the situation can be given by an analogy, namely the elevation of the earth's surface above sea level. There are general trends in elevation across Maryland, but also throughout much of the State there are regions of local irregularity such that the elevation changes 50 feet or more within a fraction of a mile. Since the changes of elevation can be seen, it is feasible to prepare maps of equal elevation (topographic maps) with a reasonable amount of work.

There are similar variations in the earth's magnetic field; but the irregularities cannot be seen. An observation at a point tells only the value for that point. The real lines of equal declination (at a given moment) are a very complex system of bends, loops, and closed curves, and cannot be drawn accurately without observations many, many times as numerous as are available.

TABLE II

Values of Magnetic Declination, January 1945

Station	Date Established	Date of Last Observation	Declination Jan. 1, 1945		Latitude		Longitude	
Carroll County								
			Degrees	*Minutes*	*Degrees*	*Minutes*	*Degrees*	*Minutes*
Blocks	9/18/39	9/18/39	7	08W	39	42	77	05
Auxiliary A	9/18/39	9/18/39	7	09				
Hampstead	9/22/39	9/22/39	7	22	39	36	76	51
Auxiliary A	9/22/39	9/22/39	7	37				
Auxiliary B	9/22/39	9/22/39	7	29				
Manchester	5/19/99	5/19/99	7	48	39	40	76	53
Sykesville	5/16/99	5/16/99	8	34	39	22	76	58
Taneytown	5/19/99	5/19/99	7	08	39	40	77	11
Westminster C.H.	10/8/96	10/8/96	7	28	39	35	77	00
Westminster N.M.	6/18/00	10/15/34	6	57	39	35	77	00
Westminster S.M.	6/15/00	6/15/00	6	52	39	35	77	00
Westminster 1939	9/19/39	9/19/39	7	01	39	36	77	00
Auxiliary A	9/19/39	9/19/39	7	03				
Auxiliary B	9/19/39	9/19/39	7	08				
Frederick County								
Boundary Monument No. 83	9/15/39	9/15/39	5	25	39	43.2	77	21.2
Auxiliary A	9/ 8/39	9/ 9/39	6	13				
Auxiliary B	9/ 8/39	9/ 8/39	6	41				
Auxiliary C	9/ 9/39	9/ 9/39	6	12				
Auxiliary D	9/15/39	9/15/39	5	40				
Auxiliary E	9/15/39	9/15/39	5	34				
Auxiliary F	9/ 8/39	9/ 9/39	5	55				
Frederick (Asylum)	10/5/96	10/ 5/96	6	58	39	25	77	25
Frederick C. H.	10/7/96	10/ 7/96	6	57	39	25	77	25
Frederick N.M.	5/13/30	5/29/40	7	07	39	26	77	26
Frederick S.M.	9/13/39	9/13/39	7	06	39	26.0	77	25.6
Auxiliary A	9/13/39	9/13/39	7	07				
Graceham	9/11/39	9/11/39	7	14	39	37	77	22
Auxiliary A	9/11/39	9/11/39	6	57				
Auxiliary B	9/11/39	9/11/39	7	06				
Auxiliary C	9/11/39	9/11/39	7	14				
Lewis	9/20/39	9/20/39	6	58	39	33	77	26
Auxiliary A	9/20/39	9/20/39	6	56				
Liberty	9/12/39	9/12/39	6	50	39	29	77	16
Auxiliary A	9/12/39	9/12/39	6	50				
Libertytown	5/20/99	5/20/99	6	55	39	29	77	14
Toms	9/16/39	9/16/39	7	14	39	41	77	16
Auxiliary A	9/16/39	9/16/39	7	13				

Interpretation of the Chart

A value scaled from a chart is strictly valid only for the year given as the epoch of the chart, but it may be reduced to another date by applying a correction for secular change. For the chart given in this chapter, the correction is to be obtained from Table III.

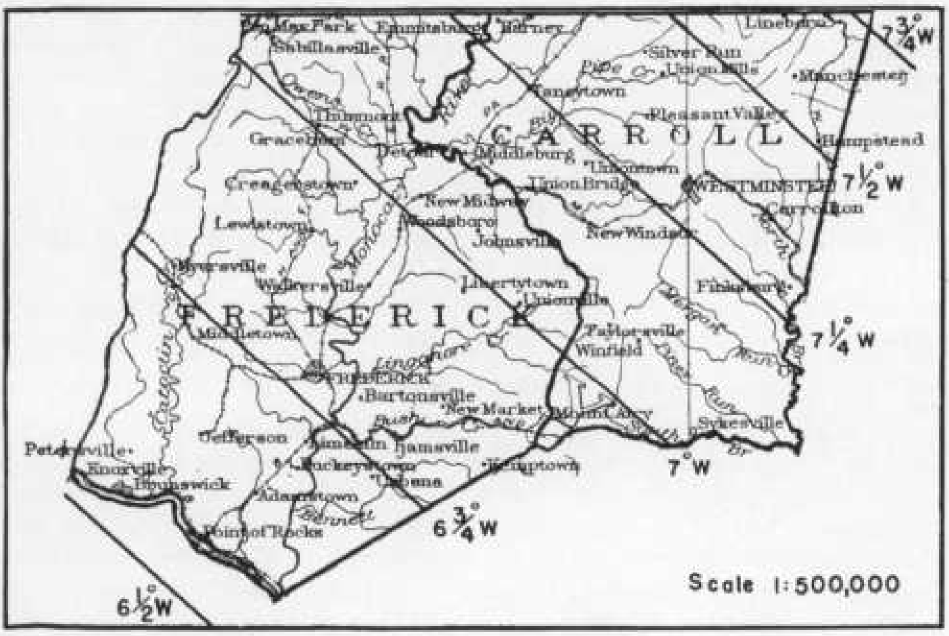

FIG. 31. Isogonic chart of Carroll and Frederick Counties for 1945.

A value obtained from a chart is to be considered as the mean for several days, with the daily variation and irregular fluctuations averaged out.

A chart value is not, in general, the actual value at the point of observation, because of the effect of local disturbace. It may be considered as the *normal value* for the point, which is approximately equal to the mean for a fair-sized region centered at the point. For the United States, there is perhaps an even chance that a value of declination scaled from a chart issued by the Coast and Geodetic Survey will be within one-half degree of the actual value. Occasionally, the true value and the chart value differ by many degrees.

The accuracy of values obtained from a chart may be judged somewhat by the agreement between chart and observations in the region. Where the observed values differ markedly from the values scaled from the chart, the region is disturbed to the amount of the differences or even more. One should remember that there may be local disturbance where none is indicated by surrounding stations, and also that an anomalous observed value may be due to a disturbed area of very limited extent; but in general the difference between chart and observations in any region is a fair guide to the reliability of a chart value in that region.

Requests for out-of-print isogonic charts are occasionally received in conjunction with inquiries which evidently pertain to secular changes. It should be understood that such charts, even if they were available, would be apt to give false results when used to determine secular change. The difference obtained for a given place by a comparison of charts for different epochs is by no means due entirely to secular change. The reason for this is that magnetic charts vary from edition to edition in regard to the delineation of local features in the distribution of the magnetic elements. This is an inevitable result of increased understanding of the subject resulting from an ever greater store of observational data. The method of computing secular change used and recommended by the Coast and Geodetic Survey does not involve the use of isogonic charts but is based entirely on tables prepared expressly for the purpose.

Even though the user is not primarily interested in secular change as such, the early isogonic charts are not suitable for obtaining the best estimate of former values of declination, because of the sparsity of the data on which they are based. It is better to use the latest chart and apply a correction for secular changes based on suitable secular-change tables rather than on any former charts.

LOCAL MAGNETIC DISTURBANCE

The declination changes from place to place. The rate of change is generally small, so that for the survey of a small area the declination may be considered constant. However, in some regions the declination changes considerably within a short distance, occasionally several degrees within a hundred feet or less; and in some places considerable differences have been noted when a slight change was made in the height of the compass above the ground. In such a region, *local disturbance* or *local anomaly* is said to exist. If it is caused by the works of man, such as pipe lines, steel structures, etc., it is said to be *artificial disturbance*; otherwise, it is *natural disturbance*.

Local disturbance is often called *local attraction*, but this is a misleading term insofar as it represents the disturbance as a force urging the compass needle toward an attractive mass. It should be emphasized that any such force is insignificant. Even the more plausible view that the needle is merely deflected in the direction of a magnetic mass is almost always an over-simplification, the disturbance being generally too complex to be described in terms of a center of attraction. The term *local irregularity* is perhaps more descriptive than is "local disturbance."

The presence of local disturbance may usually be detected quite readily by observing the compass bearing of a line at two or more points on that line. If the compass bearings of the line are the same at the different points, the area is probably free of local disturbance.

Natural Disturbance

Extreme natural disturbances or anomalies (those of several degrees or more) are usually ascribable to the presence of an iron ore called magnetite. However, there are other ores and geological formations which may cause lesser irregularities. Even in regions considered free from local disturbance, minor irregularities are common because of the widespread distribution of slightly magnetic material in the soil and rocks. For this reason it is not possible to give an accurate value of the declination at a specific point unless it has been actually measured at that point.

An area of local disturbance in the vicinity of Gaithersburg, Montgomery County, has been surveyed by the Coast and Geodetic Survey. It is known to extend into Frederick and Carroll Counties.

The effect of magnetic material diminishes rapidly with increasing distance. Hence, pronounced disturbances are less common at sea than on the land (the nearest disturbing matter usually being no nearer than the bottom of the sea). Likewise, when an airplane is in flight its compass is far from any source of natural disturbance. For both sea and air navigation, the principal uncertainties of the compass are the effect of the iron in the craft itself and the dynamical effects of the craft's motion.

Local disturbance is not to be regarded solely as an inconvenient obstacle. The study of such irregularities (especially in the vertical intensity) has led to the finding of important natural resources such as oil and minerals buried beneath the surface which are often associated with geological formations that can be traced by magnetic methods.

Artificial Disturbance

Whenever magnetic observations are being made for any purpose, the possibility of artificial magnetic disturbance should be borne in mind. Any iron or steel or direct electric current near the instrument will have an effect, the magnitude of the effect diminishing rather rapidly with increasing distance.

At sea, the iron of a ship is a source of artificial magnetic disturbance. However, means have been found to compensate for the effect on the compass.

On land, there may be iron in buildings, fences, or buried pipes. Electric currents may be encountered in all sorts of installations. Fortunately, alternating currents have no perceptible effect on the ordinary compass, since the direction of the resulting magnetic field changes so rapidly that the compass cannot respond to it. However, power lines are often supported by steel towers large enough to have considerable effect. The most troublesome source of artificial disturbance is a direct-current electric railway using grounded rails for the return current, since the leakage current may affect sensitive instruments located several miles from the railway. For ordinary compass surveys, it is considered that a quarter mile from such a railway is sufficient.

In selecting the site for a magnetic station, care must be taken to avoid natural disturbance (unless the purpose is to investigate the disturbance), and as far as possible to avoid regions in which artificial disturbance is present or likely to occur in the future. At repeat stations, where observations are repeated at intervals of five or ten years, freedom from artificial disturbance is especially important. Since, however, it is usually impossible to foresee industrial developments for many years ahead, an undesirably large number of magnetic stations become unusable because of artificial disturbance, caused by magnetic materials or electric currents. Many stations established in cemeteries, which were formerly considered ideal sites for the purpose, have been affected in recent years by the steel burial vaults now used.

USING MAGNETIC STATIONS IN NEW SURVEYS

Since the surveyor's compass is likely to get out of order, the accuracy of a compass survey will depend on the care with which the compass is adjusted. A sluggish needle may be caused by loss of magnetism, a dull pivot, or a damaged jewel. The peep sights should be vertical and the needle horizontal.

There are two distinct ways of using a magnetic station in connection with a new compass survey. The first method transforms the observed compass bearings into true bearings; the second method transforms them into correct magnetic bearings.

REFERING COMPASS SURVEYS TO THE TRUE MERIDIAN

Since the direction of the compass needle is continually changing, and since different compasses may not agree to the required accuracy, it is desirable to provide means for referring the compass bearings to a true meridian in every compass survey. The true meridian is the observer's plane through the earth's axis of rotation. The best method of determining its actual direction (assuming that there is no triangulation station within convenient distance) is to determine the true bearing of one of the lines of a survey by observations on Polaris or the sun. This is not feasible for every survey. For this reason it is important to maintain a true meridian line in the field of operations, where the surveyor may determine, at any time, the apparent value of the magnetic declination with the compass which is being used for the particular survey. The value of the declination so obtained may be recorded with the survey made at the time. When, in later years, another surveyor wishes to retrace the lines of the survey, he may redetermine the magnetic declination at the same station on the same meridian line and the difference between the old and the new values of the declination is the correction to be applied to the compass bearings of the earlier survey, provided no local disturbance has been introduced.

Legislation

The importance of testing surveyors' compasses has been recognized in several States by the passage of laws requiring the establishment of meridian lines and the testing of surveyors' compasses. Unfortunately, in many cases the location of the meridian line was not such as to insure freedom from present and future artificial disturbances, and in others either the compass tests were not made or the results not recorded, so that the object of the laws has not been fully attained.

The following are extracts from the Maryland Code, 1939, article 25, sections 137, 139 and 141:

137. It shall be lawful for the county commissioners of each county in the State, if they shall deem it expedient, to cause to be erected at some public spot adjacent to the courthouse of each county, two good and substantial stone pillars, one hundred feet distant apart, the one from the other, and upon the same true meridian line, ... the said pillars and enclosures to be subject to the custody of the county clerk, to be free to the access of any surveyor of lands or civil engineer residing in said county, or engaged in surveying therein, for the purpose of testing the variation of the compass for the time being, and to cause the said meridian line to be verified at any time when required so to do by order of the circuit court for the said county....

139. It shall be the duty of each and every surveyor surveying land in any county of this State that shall adopt the provisions of the two preceding sections to test and note the actual variation of his compass from the aforesaid true meridian line at least once in every year, and to deposit a copy of the same, with the date and time of such test, accompanying the same with affidavit verifying its correctness, with the clerk of the county in which he may reside, to be by him recorded in a book kept for that purpose, and every surveyor neglecting or refusing to comply with the provisions of this section, shall be liable to a penalty of fifty dollars, to be recovered before any justice of the peace in the county. . . .

141. Any person or persons who shall wilfully erase, deface, displace, or otherwise injure said pillars, or any part thereof . . . shall, upon conviction thereof, be punished by a fine of not less than fifty nor more than five hundred dollars.

DESCRIPTIONS OF MAGNETIC STATIONS

A station that is to be used in the way described above may be a marked magnetic station, or any other marked station at which a true azimuth is known, provided it is reasonably free from local magnetic anomaly. Descriptions of the magnetic stations in these counties are given below; brief descriptions of the unmarked ones are included for completeness, although these cannot be used for this purpose.

If a surveyor should wish to use a triangulation station of the Coast and Geodetic Survey in the way described above, he may obtain a description by request to the Director, U. S. Coast and Geodetic Survey, Washington 25, D. C.

In recent years, most of the magnetic stations of the Coast and Geodetic Survey have been marked by a bronze disk $3\frac{1}{2}$ inches in diameter, with a double triangle and the legend "MAGNETIC STATION" cast into it. There are 4 stations in these counties that are so marked. In addition, one station is marked as a triangulation station and one as a reference mark.

At both Westminster and Frederick there are meridian lines (two stones due north and south of each other). These are counted as separate stations, since magnetic observations have been made at each one. In making a record of any compass tests, the record should show which stone was used.

At stations without a meridian line, the direction of the true meridian can be determined readily if the true azimuths of one or more prominent objects are given in the description. There are two such stations in these counties, namely Blocks and Boundary Monument No. 83. The true azimuths given are to be set off on the horizontal circle of the instrument, to give the true meridian. In using these objects, care should be taken to insure proper identification, preferably by measuring the angle between two objects. (Observers attempt to select objects about which there can be no confusion, but this is not always possible; also, in some cases significant changes have occurred since the azimuths were determined.)

The true azimuths are reckoned from 0° to 360°, as follows: 0° = south; 90° = west; 180° = north; 270° = east; 360° = south. They may be transformed into bearings reckoned from 0° to 90° as shown in the following examples:

Azimuth of 21° = Bearing of S. 21° W.
Azimuth of 160° = Bearing of N. 20° W.
Azimuth of 200° = Bearing of N. 20° E.
Azimuth of 300° = Bearing of S. 60° E.

The same relation is true for magnetic azimuth and magnetic bearing. (The above convention for azimuth is used in all the land work of the Coast and Geodetic Survey; in work on the water or in the air, azimuth is counted from the north around by east.)

On the average, the true azimuths were determined with a "probable error" of about 1 minute; that is, there is about an even chance that a stated true azimuth is within 1 minute of the correct value, excepting, of course, cases in which an object has been moved since its azimuth was determined. The probable error of 1′ applies also to the setting of a meridian line.

With the cooperation of local surveyors and others it has been possible to secure comparatively recent information regarding the availability of many of the stations. *As the maintenance of these stations is of great importance to local surveyors as well as to the Coast and Geodetic Survey, persons in control of a station site are earnestly requested to protect the marker from disturbance so far as possible and to inform that office if conditions develop which may affect the usefulness of the station.*

It should be understood that when the description says the stone is "north," for example, from a given object, it means merely that it is in a general northerly direction.

The descriptions have been revised for all information available in the office of the United States Coast and Geodetic Survey on March 1, 1945.

CARROLL COUNTY STATIONS

Blocks (last report, 1939).—The magnetic station coincides with the azimuth mark of triangulation stations BLOCKS. It is about 5 miles northeast of Taneytown and about a mile south of the Pennsylvania line.

From the intersection of Highways 32 and 71 in Taneytown, go northeast on No. 71 for 5.3 miles to State line, continue north 0.45 mile to crossroads, turn right on paved road, go 0.9 mile to forks at old mill at end of pavement just beyond bridge, take right fork and go 1.4 mile to a reverse *Y* intersection and canning plant on left, turn left and go around north side of factory, follow lane to first sharp left turn. Then go south across field 0.1 mile to top of ridge and magnetic station.

The magnetic station is in the west edge of a woods, 8 feet south of a 6-inch oak. It is marked by a bronze disk in the top of a concrete post; the disk has an arrow pointing toward the triangulation station.

The following true azimuths were determined from the magnetic station:

	Degrees	*Minutes*
Center of white column farthest to right on porch of large white house	3	49.7
Triangulation station BLOCKS, 0.6 mile away, on top of highest hill in vicinity	43	54.9
Southeast corner of roof edge of a green dwelling near canning factory	119	12.7
Center, at base, of northernmost stack of canning factory	131	17.4

One unmarked auxiliary station was established to test for local disturbance.

Hampstead (last report, 1939).—The magnetic station was an unmarked point 2372 feet southeast of the triangulation station of the same name, and 210 feet southeast of its azimuth mark, on the extension of the line joining the two markers. Two unmarked auxiliaries were established in the vicinity, to test for local disturbance.

Manchester (last report, 1899).—The station was in the lot back of the schoolhouse and Methodist Church, 37 feet east of a large cherry tree and 104.3 feet from the northwest corner of the schoolhouse.

Sykesville (last report, 1899).—The station was in the large open field about 300 feet back of the new brick schoolhouse.

Taneytown (last report, 1927).—The station was in the yard back of Prof. Henry Meier's academy; 307 feet from the west fence, 19.2 feet from the east fence, and 62.8 feet from the north corner of a small frame house. In 1927, the station could not be located.

Westminster C.H. (last report, 1896).—The station was established by the Maryland Geological Survey. It was in the grounds back of the courthouse, about 22 paces west of the back entrance and near the edge of the pavement.

Westminster N.M. (last report, 1934).—The station is on the grounds of Western Maryland College, 54 feet south of the center of the road leading across the athletic field, and 100 feet southwest of a wild cherry tree in a fence corner. The station is marked by a round granite post with a bronze disk in the top, which is 6 inches above ground. The following true azimuths were determined:

	Degrees	*Minutes*
Center of cross on seminar building on college grounds	11	27.8
Point of cupola on building in corner of cemetery	155	14.4
Center of cross (on red brick) in north corner of cemetery	166	18.6
Church spire	341	07.5

Westminster S.M. (last report, 1934).—This station is due south of Westminster N.M., in the rear of the Seminary building. It is marked in the same way as Westminster N.M.

Westminster 1939 (last report, 1939).—The magnetic station was an unmarked point in the northeast corner of a cemetery, 4217 feet NNW of the triangulation station WESTMINSTER. It was about 300 feet SSE of the azimuth mark of that triangulation station, and on a direct line between the two markers. Two unmarked auxiliary stations were established in the vicinity to test for local disturbance.

FREDERICK COUNTY STATIONS

Boundary Monument No. 83 (last report, 1939).—The magnetic station is an exact occupation of the triangulation station of the same name, which is one of the Mason-Dixon markers. It is on the State line, and on the property line between Mr. Cluck on the north and the Harner Estate on the south. It is on the slope of a hill, 200 yards south of Mr. Cluck's house, 10 feet south of a cultivated field, in a pasture lot east of an orchard. The marker is 10 inches square and is chipped at the corners; "P" is engraved on the north face and "M" on the south face. It projects 16 inches above ground.

Two reference marks and an azimuth mark were set; they are concrete posts with bronze disks in the tops. Reference mark No. 1 is 1 foot east of the orchard fence, and projects 12 inches above ground. No. 2 is 2 feet east of a fence corner, 25 feet east of a 10-inch apple tree, 21 feet west of a 10-inch apple tree, and 50 feet west of a chicken house. The reference marks are intended primarily to assist in locating the station, rather than for azimuth.

The azimuth mark is 0.5 mile south of the station, on land owned by Mrs. Florence. It is 50 feet east of the center of State Highway 32, and projects 4 inches. To reach it from the station, go to Mr. Cluck's house, turn right on highway, and go 0.5 mile to azimuth mark on left.

The following true azimuths were determined:

	Degrees	Minutes
Reference mark No. 1, 54.318 meters away	79	47.4
Reference mark No. 2, 64.041 meters away	161	25.4
Azimuth mark, 0.5 mile away	306	48.9

Six unmarked auxiliary stations were established to test for local disturbance. Considerable disturbance was found, due to magnetic rocks.

To reach the station from the junction of U. S. Highway 15 and State Highway 32 in Emmitsburg, go northwest on No. 32 for 1.75 miles to the State line; continue 0.1 mile to Mr. Cluck's house, turn left on north side of house and bear left (south), 200 yards to station.

Frederick (*Asylum*) (last report, 1896).—The station was established by the Maryland Geological Survey in the southeast part of the grounds back of the State Deaf and Dumb Asylum.

Frederick C.H. (last report, 1896).—The station of the Maryland Geological Survey was the north meridian stone in the grounds on the east side of the courthouse.

Frederick N.M. (last report, 1940).—The station is about 1.7 miles northwest of the center of the city, near the southeast corner of the municipal airport. It is 465 feet northwest of the northwest corner of the steel tower at the airport, 86.2 feet southwest of the fence along the highway, and 248.5 feet south of the nearest corner of a concrete culvert on the highway. It is marked by a bronze disk set in the top of a concrete post 12 inches in diameter and 24 inches long, which is flush with the ground.

The following true azimuths were determined:

	Degrees	Minutes
Flagpole on north cupola of almshouse	67	56.5
Center of round window on north cupola of almshouse	67	54.5
Beacon in line with barn at almshouse (beacon is in Braddock Heights)	74	01.6
Gable above columns on Mr. Bright's farmhouse	117	54.1
Hamburg fire tower, in line with bend in highway	152	36.4
Right edge of brick farmhouse near north corner of airport	163	46.6
Left edge of main upper portion of concrete culvert on highway	166	22.9
Apex of light on steel tower at airport (beacon)	322	03.3
Center of brick stack	343	09.0
South meridian stone	359	59.9

Frederick S.M. (last report, 1940).—This station is 727.8 feet due south of Frederick N.M., and is marked in the same way. It is in a macadam road, and projects

2 inches above the road bed. It is 5 feet west of the east edge of the road, 25 feet east of the west edge of the road, 61 feet west of a tree, 28 paces north of the north corner of T. M. Lescalleet's residence, 453.2 feet southwest of the south corner of the steel tower, 155 feet northeast of a NW–SE pipe line, and 6 feet northwest of a covered 4-inch cast iron pipe line running NE–SW. (This last pipe is near enough to cause considerable artificial disturbance, but the declination was not materially affected by it at the time the last observations were made.)

The following true azimuths were determined:

	Degrees	Minutes
Center of highest small window near top of most northerly dome of Frederick County Emergency Hospital	79	23.4
Center, at base, of most northern red and white airport boundary pole	165	39.7
Triangulation station FREDERICK, 157.707 meters away	215	13.9
Center of large white brick stack in Frederick	340	19.9

Graceham (last report, 1939).—The magnetic station was an unmarked point in the center of a small pasture. It was directly between triangulation station GRACEHAM and its azimuth mark, about ½ mile northeast of the former and 500 feet southwest of the latter. Three unmarked auxiliaries were established to test for local disturbance.

Lewis (last report, 1939).—The magnetic station was an unmarked point in the east edge of a small cornfield. It was on an extension of the line joining triangulation station LEWIS and its azimuth mark, about 5000 feet northwest of the former and 115 feet northwest of the latter. One unmarked auxiliary station was established to test for local disturbance.

Liberty (last report, 1939).—The magnetic station was a unmarked point near the center of a cornfield. It was directly between triangulation station LIBERTY and its azimuth mark, 5070 feet south of the former and about 700 feet north of the latter. An unmarked auxiliary station was established to test for local disturbance.

Libertytown (last report, 1899).—The station was established by the Maryland Geological Survey in the large lot back of the schoolhouse and opposite the Liberty Hotel. It was 167.9 feet from the north front of the schoolhouse, and 25.5 feet from the line of locust trees on the west side.

Toms (last report, 1939).—The magnetic station was an unmarked point, directly between triangulation station TOMS and its azimuth mark, 4977 feet ENE of the former and about 400 feet WSW of the latter. An unmarked auxiliary station was established to test for local disturbance.

COMPASS CORRECTION

The angle between the observed direction of the needle of a given compass and the actual magnetic meridian prevailing during the observations is known as the *compass correction* or *index correction.* This correction may be determined by observing at one of the magnetic stations described above, making use of the declination shown in Table II. It is advisable to make two or more tests on different days and at different hours (preferably early morning and late afternoon).

A value given in Table II, like one scaled from an isogonic chart, is intended to represent a mean for a period of several days or a month; the value at any particular moment is usually greater or less than the mean as a result of daily variation and irregular fluctuations. If extreme precision is required, the Coast and Geodetic Survey can furnish an estimate of the amount of these changes, if the date and time for which they are needed are given. Such an estimate would be based on the records of the Cheltenham Magnetic Observatory, and could be given perhaps two weeks after the date in question.

Appreciable errors in a compass correction derived in this way may at times arise from artificial disturbance introduced at the station without the knowledge of the Coast and Geodetic Survey. Such artificial disturbance sometimes renders a station wholly useless for testing a compass. It should always be understood that the value given for a station is applicable only if no artificial disturbance has been introduced since the last observations were made. This date is shown in Table II.

There is another source of uncertainty in the data in Table II, namely the reduction for secular change. This uncertainty is of the order of 0.2′ or 0.3′ for each year since the date of last observation.

Table II gives the declination for January 1945 for each magnetic station at which it was determined by the Maryland Geological Survey or by the United States Coast and Geodetic Survey. Most of the stations were not permanently marked; however, the values are included in Table II to show the data available for preparing the isogonic chart. Similarly, some of the stations have been rendered useless by artificial disturbance; the table shows what the declination would be at present if the artificial disturbance were completely removed.

For most of the observations, a correction for daily variation and irregular disturbance has been applied, intended to reduce the observed value to mean of the month. The corrections were usually based on the records of the Cheltenham Magnetic Observatory.

If observations have been made more than once at a station, only the last ones were used for Table II. If observations were made at two or more nearby points, all of them are included. The one at which most of the observations were made is shown first, the others usually being called "auxiliaries."

Positions not determined by triangulation are stated to minutes only, the "probable error" being about 1 minute in longitude and somewhat less in latitude. Positions determined by triangulation are stated to tenths of a minute.

RETRACING OLD LINES ORIGINALLY RUN BY COMPASS

GENERAL PRINCIPLES

The known angles at the corners of a tract may be inconsistent with the recorded bearings of the lines. It was once a rather common practice to make compass surveys without actually measuring the angles at the corners of the tract. That is, only one pointing of the compass would be made at each corner, this being a sight to the next corner. Under these circumstances, the various bearings will necessarily reflect any irregularities of declination which may characterize the site. Although the bearings may have been reduced to "true" bearings by applying a constant correction for the average declination prevailing at the time of the original survey, such reduction would not rectify the irregularities mentioned.

If a reduction for declination has been made, any error in the original estimate of the declination will be incorporated in all the recorded "true" bearings. A systematic error arising from this or other cause may make it impossible to pre-determine the relation between the recorded bearings of a tract and the present magnetic bearings of the same lines. However, in view of the irregularities mentioned above, it may still be advantageous to use a compass in the resurvey in order best to duplicate the differences of successive bearings. That is, the differences would be expected to correspond to those derived from the earlier survey despite the systematic error, it we assume that the magnetic bearings of any one survey are all affected alike by the secular change. If, however, there is local disturbance in the region, it would be necessary to set up the compass at the same points as was done in the original survey if errors from this source are to be avoided.

While an understanding of former practice is thus helpful in recovering old lines, the application of the more up-to-date procedures described previously is an essential precaution against the future recurrence of difficulties of the same kind. The assumption that the various azimuths of a tract are similarly affected by secular change usually holds good, provided there has been no change in the distribution of local disturbance during the interval. Such alterations may occur in the vicinity of metal structures and where electric currents are present in the ground, as from nearby electric railways.

Resurveys are sometimes complicated by errors of previous resurveys. Thus, sometimes compass bearings given in one deed are repeated in another one, perhaps 50 years later, when the bearings may have changed a degree or more. Sometimes when property is subdivided the old bearings of the old lines are given in the new deed, but the bearings of the subdividing lines are given as observed at the time of the subdivision.

Annual-change rates or mathematical formulas should not be used to compute secular changes for extended periods. At one time such formulas were published by the Coast and Geodetic Survey (some of them are given in the First Report on the Magnetic Survey of Maryland).

Each such formula was intended to be used only for periods of time within the interval covered by the basic data. Even for such periods, the formulas are now superseded by information published in the form of tables such as Table III, which is more accurate because of the application of graphic methods based on a better understanding of the nature of secular changes. It is now considered that the normal rates of secular changes in different parts of a region at any given time exhibit a gradual and smooth gradation from place to place, quite different from the marked local irregularity characteristic of the magnetic elements themselves. (The latter irregularities do, of course, have some effect on the secular change of some of the elements, but not sufficient to obscure the fact of the smooth basic distribution.) In the tables of secular change, advantage has been taken of this fact by the substitution of spatial or geographic smoothness for the extreme chronological smooth-

TABLE III

Secular Change of the Magnetic Declination

The following table shows the approximate mean magnetic declination at the beginnings of the specified years at the sites now occupied by the specified magnetic stations. Because of the paucity of early data, the middle portion of the table is uncertain by 15′ or perhaps 30′, and the older portion by 1° or more.

Year	Westminster N.M.		Frederick N.M.		Year	Westminster N.M.		Frederick N.M.		Year	Westminster N.M.		Frederick N.M.	
	Degrees	*Minutes*	*Degrees*	*Minutes*		*Degrees*	*Minutes*	*Degrees*	*Minutes*		*Degrees*	*Minutes*	*Degrees*	*Minutes*
1650	5	13W	5	33W	1770	1	05W	1	25W	1890	4	12W	4	27W
1660	5	33	5	53	1780	0	36	0	56	1900	4	49	5	04
1670	5	45	6	05	1790	0	16	0	35	1905	5	08	5	23
1680	5	46	6	06	1800	0	06	0	25	1910	5	30	5	44
1690	5	37	5	57	1810	0	06	0	24	1915	5	52	6	05
1700	5	19	5	39	1820	0	16	0	33	1920	6	08	6	21
1710	4	53	5	13	1830	0	36	0	52	1925	6	28	6	40
1720	4	20	4	40	1840	1	05	1	20	1930	6	45	6	56
1730	3	41	4	01	1850	1	39	1	54	1935	6	58	7	09
1740	3	01	3	21	1860	2	16	2	31	1940	6	56	7	07
1750	2	21	2	41	1870	2	56	3	11	1945	6	57	7	07
1760	1	41	2	01	1880	3	36	3	51	1950	6	56W	9	06W
1770	1	05W	1	25W	1890	4	12W	4	27W					

ness resulting from the use of the formulas. Furthermore, it has been amply demonstrated that those formulas do not apply to the secular change which has occurred since their publication in the last century, thus giving point to the warning which always accompanied such formulas, that they were not to be used for predictions of future changes. Unfortunately, the old formulas have in some instances been quoted by authors who failed to include the precautionary notes.

When a surveyor is called upon to redetermine the boundary lines of a tract of land originally surveyed by compass and can find in the vicinity a well-defined line, known to have been established with the same compass at about the same time as the lines of the tract in question, he can do no better than determine the amount of change in the compass bearing of that well-defined line and use it to obtain the present compass bearings of the boundary lines to be established. In this way the effects of possible index corrections in the two instruments and of the uncertainty in the secular-change data will be eliminated. Only in the absence of such definite information is the use of secular-change tables recommended.

SECULAR-CHANGE TABLE

Derivation of Secular-Change Tables

The Coast and Geodetic Survey has made a careful study of old observations of the magnetic elements, and has prepared "secular-change tables" showing the approximate changes in all parts of the United States from an early date to the present time. The latest editions of these tables are published in Serial 592 for

TABLE IV

Secular Change of Magnetic Declination at Cheltenham Magnetic Observatory

(The values are the means for the ten least disturbed days of each month.)

[Cheltenham is in Prince Georges County, Maryland. Latitude, 38° 44′; Longitude, 76° 51′.]

Year	Declination	Year	Declination	Year	Declination	Year	Declination
	Degrees Minutes		*Degrees Minutes*		*Degrees Minutes*		*Degrees Minutes*
1902	5 06.8W	1913	5 54.6W	1924	6 35.8W	1935	7 06.5W
1903	10.0	1914	5 59.8	1925	39.4	1936	06.2
1904	13.3	1915	6 04.0	1926	42.8	1937	04.9
1905	17.8	1916	07.7	1927	45.7	1938	05.1*
1906	21.5	1917	10.4	1928	49.0	1939	05.0*
1907	26.0	1918	12.4	1929	52.0	1940	04.8*
1908	31.1	1919	15.0	1930	6 55.9	1941	05.4*
1909	36.4	1920	18.5	1931	7 00.0	1942	05.9*
1910	41.4	1921	22.4	1932	03.7	1943	06.3*
1911	45.6	1922	27.7	1933	06.2	1944	06.0*
1912	50.0	1923	32.0	1934	06.8		
1913	5 54.6W	1924	6 35.8W	1935	7 06.5		

* Provisional value, based on all days.

declination, and in Serial 602 for dip and horizontal intensity. The portion of Table III from 1750 to 1935 has been derived from Serial 592; that since 1935, from unpublished results which will appear in Serial 664; and the portion previous to 1750 from very approximate tables given in "United States Magnetic Declination Tables and Isogonic Charts for 1902."

There are very few stations in the United States for which we have accurate results as early as 1850, and it has usually been impossible to make later observations at the exact spot at which those early ones were made. Even in recent years, when magnetic stations are selected with particular refrence to future availability, it sometimes happens that a station is no longer suitable for use after 5 or 10 years.

The secular change prior to 1855 is based on data collected from various sources, limited in amount and of varying degrees of accuracy. Considerable information has been received from local surveyors, based on their experience in retracing the lines of old compass surveys. Since 1855 the Coast and Geodetic Survey has made magnetic observations that can be used to determine secular change, and since 1900 it has been making systematic observations for this purpose at the repeat stations and magnetic observatories previously described. The changes thus observed enable one to estimate the changes at other places with sufficient accuracy for most purposes.

Description of Secular-Change Table

Table III gives the approximate magnetic declination at one magnetic station in each county at intervals of 5 or 10 years. The values for other years may be found by linear interpolation between the published values. The change is not actually uniform from year to year, as is illustrated by Table IV, but the error resulting from using a uniform change is not significant for surveying purposes. Furthermore, for most of the period covered by Table III, no data are available upon which more detailed changes could be given.

The tables extend back to 1650, but the earlier part of the table, especially the portion previous to 1750, is very uncertain.

Since the secular change follows no known law, it is not safe to predict it more than a few years in advance. Table III gives estimated declination for 1950; but it should be understood that a sudden alteration in the rate of change (similar to that which occurred in 1933) may affect the 1950 value appreciably; and extrapolation beyond 1950 should not be attempted.

Use of Secular-Change Table

Before the table is used in resurveying an old line, it should be determined, by reading the preceding section on "general principles," that there is no better way of proceeding.

In using Table III, the surveyor should bear in mind the uncertainties incident to the use of the compass, and should not be surprised if, for example, the change of declination since the early part of the nineteenth century, as given by the tables, differs by as much as 30 minutes from the value indicated by his own retracing of old lines. Even at the present time some compasses are in error by as much as a quarter of a degree, owing to imperfections in construction, to lack of proper care, or to other causes. Without doubt, such conditions were much worse a century ago. Moreover, while the data are intended to give the actual change in the magnetic declination, eliminating as far as possible the errors of individual instruments, they are only approximate, and the earlier portions are less reliable on account of the inferior character and limited number of observations upon which they are based. The entries in Table III are stated to minutes; but this is done only to avoid the accumulation of rounding-off errors, and it should be understood that in no case are the secular changes actually known within 1′.

Secular change is affected somewhat by the presence of local disturbance, but for most regions it will suffice for ordinary purposes to use a table which describes the changes under average conditions. The secular changes shown for Westminster and Frederick may, with sufficient accuracy, be used for any other points in Carroll and Frederick Counties, repectively, even though the declination itself may be different.

BIBLIOGRAPHY

MARYLAND GEOLOGICAL SURVEY

The original magnetic survey of Maryland was reported in the following two reports:

First Report upon magnetic work in Maryland, including the history and objects of magnetic surveys, by L. A. Bauer, Maryland Geological Survey, volume I, part V, 1897, pp. 405–529. This report gave data on the declination only. Much of the description of history, objects, and methods of magnetic surveys is still of interest, although parts of it have been superseded.

Second Report on magnetic work in Maryland, by L. A. Bauer, Maryland Geological Survey, volume V, part I, 1905, pp. 23–98. This gives data for declination, dip, and horizontal intensity, and is restricted to being an actual report on the survey more closely than was the first report.

The Maryland Geological Survey has issued a number of publications similar to this one, each covering one or two counties. Each of these contained a chapter dealing with the magnetic declination.

The following has been largely if not entirely superseded by the Coast and Geodetic Survey's Serials 457 and 602:

Report on the lines of equal magnetic declination in Maryland for 1910, by L. A. Bauer, Maryland Geological Survey, volume IX, part IV, pp. 331–338.

COAST AND GEODETIC SURVEY

There is available for free distribution a leaflet describing the current publications about the earth's magnetism issued by the U. S. Coast and Geodetic Survey. This, as well as Serial 618 listed below, can be obtained from the Director, U. S. Coast and Geodetic Survey, Washington 25, D. C.

The following list shows the publications issued by the Coast and Geodetic Survey that are of particular concern to Maryland. ALL OF THESE EXCEPT SERIAL 618 MUST BE PURCHASED FROM THE SUPERINTENDENT OF DOCUMENTS, WASHINGTON 25, D. C.

Name	*Serial No.*	*Price*
Directions for Magnetic Measurements	166	$0.65
Magnetic Declination in Delaware, Maryland, Virginia, West Virginia, Kentucky, and Tennessee, 1925	457	0.20
United States Magnetic Tables and Magnetic Charts for 1935	602	0.60
Practical Uses of the Earth's Magnetism	618	Free
Magnetism of the Earth	663	0.35
Magnetic Declination in the United States in 1945	664	In press

Serial 166 is intended primarily for observers of the Coast and Geodetic Survey.

Serial 457 is one of a series of publications which give for a State or group of States full information regarding the magnetic declination, with descriptions of stations, secular change tables, and an isogonic chart. The isogonic charts in these publications show all the magnetic stations in the respective States and the observed values of declination reduced to the epoch of the chart. These reduced values are useful for showing readily whether the observations reveal any local disturbance and are useful for that purpose even when the chart is 10 or more years old, since the same anomalies would be shown if all values were reduced to 1945. The stations of the Maryland Geological Survey are included.

Serial 592, mentioned in the text, is the predecessor for 1935 of Serial 664, described below.

Serial 602 is one of a series issued every 10 years. It contains observed values of declination, dip, and horizontal intensity, together with the values reduced to 1935. It also contains folded charts for declination, dip, horizontal intensity, and vertical intensity. The volume for 1945 will be Serial 667, and will probably be issued in 1947.

Serials 618 and 663 give general discussions of the main features of the earth's magnetism, in as non-technical a manner as possible. They do not contain charts or secular-change tables. They cover approximately the same subject matter except that 663 includes a historical discussion; but 618 is much more abbreviated than is 663.

Serial 664 will be one of a series normally issued every 5 years. (The volume for 1940 was omitted because of the war.) Each volume of the series contains secular-change tables for the entire country, an isogonic chart of the United States, and directions for determining the true meridian with limited instrumental equipment. These are the standard publications for the use of land surveyors who use the compass. Serial 664 will probably be ready in 1946.

PLATE 1A. South Mountain viewed from the west, near Smithsburg, Washington County. Warner Gap Hollow at right, Raven Rock Hollow at left.

PLATE 1B. Catoctin Mountain, seen from the west, near Jefferson, Frederick County.

PLATE 2A. Parrs Ridge viewed from west. Southwest of Westminster, Carroll County.

PLATE 2B. Sugarloaf Mountain, viewed from a point 1½ miles north of Dickerson. Furnace Ridge, part of Sugarloaf range, in left distance.

PLATE 3A. Gap in Blue Ridge at Harpers Ferry, looking east downstream. South Mountain in distance. (Photograph by G. P. Grimsley.)

PLATE 3B. South Mountain gap, viewed from Keeptryst, Frederick County, looking east down river. Hill south of view capped by gravel on 500 foot terrace. Old C. and O. canal lock in foreground.

PLATE 4A. Amygdaloidal Catoctin metabasalt. Two miles east of Myersville, Frederick County.

PLATE 4B. Rhyolite breccia. Middlepoint, Frederick County.

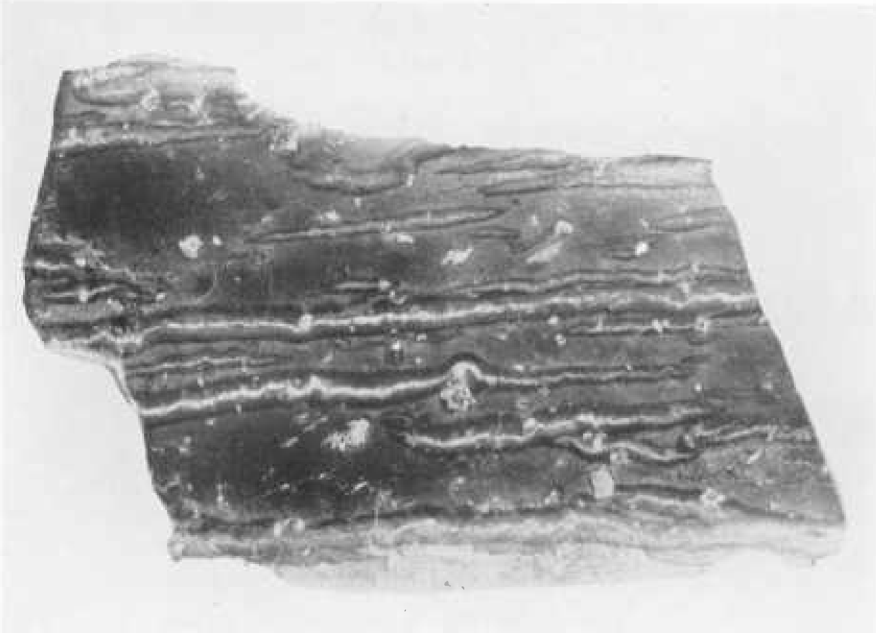

PLATE 5A. Red rhyolite banded by white spherulitic layers. South Mountain, Franklin County, Pennsylvania.

PLATE 5B. Rhyolite banded by chain spherulites. South Mountain, Franklin County, Pennsylvania.

PLATE 6A. Schistose arkosic beds of the Loudoun formation, east foot of Catoctin Mountain, west of Roddy, Frederick County. Schistosity dips steeply southeast.

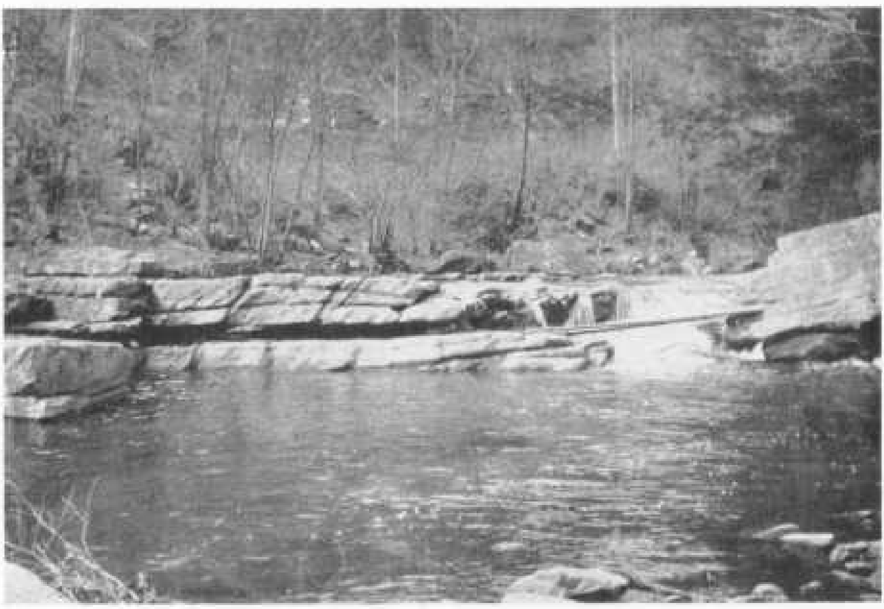

PLATE 6B. Horizontal harder arkosic quartzite in upper part of the Loudoun formation, east foot of Catoctin Mountain on north branch of Owens Creek.

PLATE 7A. High Knob, Catoctin Mountain, viewed from Ridge Hill.

PLATE 7B. Nearly horizontal plate of upper white quartzite of the Weverton, broken by clefts following vertical joints. Wolf Rock, Catoctin Mountain.

PLATE 8A. Upper white quartzite of the Weverton at Hamburg fire tower on Catoctin Mountain, northwest of Yellow Springs.

PLATE 8B. Upper quartzite of the Weverton at White Rocks, Catoctin Mountain, 2 miles northwest of Yellow Springs.

PLATE 9A. Ledges of upper white quartzite of the Weverton, Chimney Rock, Catoctin Mountain.

PLATE 9B. Nearly horizontal white quartzite of the Weverton capping the Chimney at Chimney Rock, Catoctin Mountain.

PLATE 10A. Lower hard beds of Weverton quartzite at east end of gap in South Mountain at Potomac River, east of Weverton.

PLATE 10B. Rapids in Potomac River over ledges of Weverton quartzite at gap in South Mountain east of Weverton.

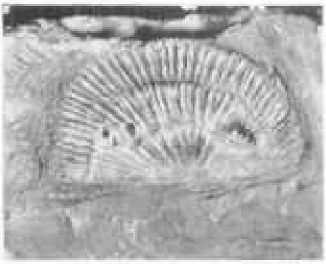

PLATE 11A

PLATE 11B

PLATES 11A, B. Fossils in Frederick limestone (photographs by G. A. Cooper). A· *zenorthis* (formerly *Straphomena*) *stosei* Bassler. B. "*acidaspis*" *ulrichi* Bassler and smaller *zenorthis stosei* Bassler.

PLATE 11C. Longitudinal valley underlain by Wakefield marble between ridges composed of overlying Sams Creek metabasalt. Valley of tributary of Sams Creek South of Englars Mill, Carroll County.

PLATE 12A. Wakefield marble overlain by Sams Creek metabasalt. Dip west. Face of quarry 1 mile south of Spring Mills, Carroll County.

PLATE 12B. Steeply inclined rocky ledges of schistose Sams Creek metabasalt, striking northeast and steep southeast-dipping schistosity at end of a fold. Englars Mill, Carroll County.

PLATE 13A. Cliff of Sugarloaf Mountain quartzite capping Sugarloaf Peak. Cliff on east side of re-entrant valley.

PLATE 13B. Cliff on Sugarloaf Mountain quartzite on knob north of headwaters of Bear Branch. Frederick Valley in distance.

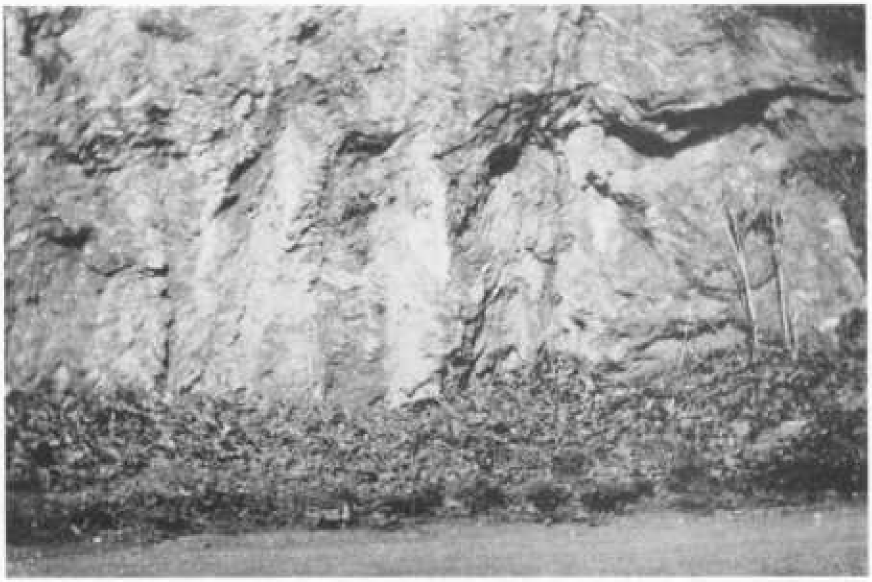

PLATE 14A. Closely folded albite-chlorite schist of Wissahickon formation in center of anticline, east of Cranberry, Carroll County.

PLATE 14B. Northwest-dipping New Oxford formation overlying Ijamsville phyllite. Railroad cut northeast of Ladiesburg, Frederick County.

PLATE 15A. Recumbent anticline of upper beds of Weverton quartzite in bluff of Elk Ridge at Potomac River (Fig. 26).

PLATE 15B. Lower beds of Weverton quartzite just east of recumbent fold shown in Pl. 15A, at east end of Elk Ridge bluff at Potomac River (Fig. 27).

PLATE 16A. Crest of recumbent fold in lower hard beds of Weverton quartzite, east end of Elk Ridge bluff at Potomac River (Fig. 27).

PLATE 16B. Harpers phyllite, west end of Elk Ridge bluff at Potomac River, north of bridge. Cleavage dips 50° SE parallel to Harpers Ferry overthrust. Bedding horizontal (Fig. 26).

PLATE 17A. Grove limestone in quarry of M. J. Grove Lime Co., southeast of Frederick.

PLATE 17B. Grove limestone in quarry of LeGore Lime Co., LeGore, Frederick County. Face at north end of quarry.

PLATE 18A. Lehigh Portland Cement Company's plant at Union Bridge looking southeast.

PLATE 18B. Soapstone mill of Clinchfield Sand and Feldspar Corporation, 1 mile northwest of Marriottsville, Carroll County.

PLATE 19A. Quarry in slabby beds of Weverton quartzite on top of Carrick Knob, Catoctin Mountain.

PLATE 19B. Reservoir on Fishing Creek, Catoctin Mountain. Frederick water supply.

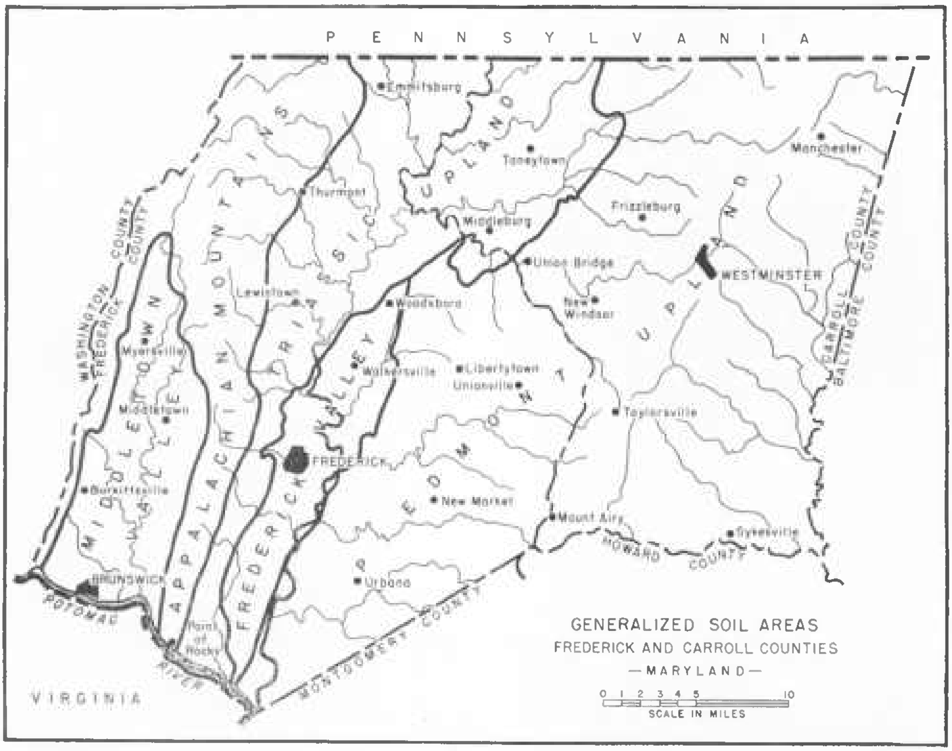

PLATE 20A. Sketch map showing five general soil areas in Carroll and Frederick Counties.

PLATE 20B. Conservation survey of area in the Piedmont Upland showing complicated pattern of slopes, and associated soil and erosion conditions. Soil, slope and erosion boundaries are shown by solid lines and land use boundaries by dashed lines. First number in compound symbol is soil type.

Moderately deep, well drained soils: 210, Glenelg gravelly loam; 211, Glenelg silt loam.

Shallow well drained soils: 1, Manor slate loam; 34, Linganore slate loam.

Deep, imperfectly drained soil: 9, Glenville silt loam.

Deep, poorly drained soil: 10, Worsham silt loam.

Imperfectly drained, floodplain soil: 133, Codorus silt loam.

Poorly drained, floodplain soil: 134, Wehadkee silt loam.

Letter in compound symbol denotes slope: A, 0–3%; B, 3–8%; C, 8–15%; D, 15–25%; and E, 25–45%.

Final number represents erosion: 0, no apparent erosion; +, recent deposition; 1, 0–25 per cent of surface soil lost; 2, 25–75 per cent of surface soil lost; 27, 25–75 per cent of surface soil lost, occasional gullies; 3, 75 per cent of surface soil to 25 per cent of subsoil lost; 37, 75 per cent of surface soil to 25 per cent of subsoil lost, occasional gullies; 38, 75 per cent of surface soil to 25 per cent of subsoil lost, frequent gullies; 0, undifferentiated erosion.

Land use is shown by letter symbols standing alone: L, cropland; P, pasture; X, idle land; F, woodland; H, residential uses.

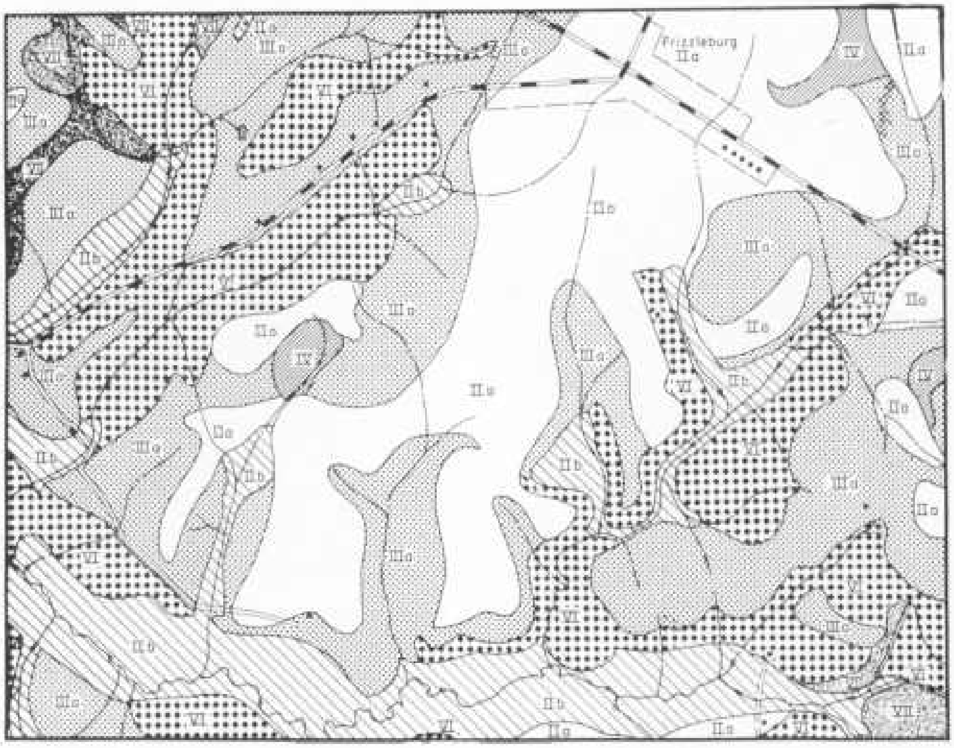

PLATE 21A. Land use capabilities of the area shown in Plate 20B. Class IIa—Suitable for cultivation with simple soil and moisture conservation practices. Class IIb—Suitable for cultivation with simple drainage practices. Class IIIa—Suitable for cultivation with intensive soil and moisture conservation practices. Class IV—Suitable for occasional or limited cultivation. Class VI—Not suitable for cultivation, but suitable for permanent pasture or woods with simple conservation practices. Class VII—Not suitable for cultivation but suitable for forest or wildlife development with intensive conservation practices.

PLATE 21B. Aerial view of a portion of the Middletown Valley showing hilly nature of the land. Soils are mainly Myersville with some Catoctin on steep slopes beyond the creek valley in the middle distance. Gullies and the galled spots which show that surface soil has been lost by sheet erosion can be seen in several fields. On the farm in the foreground and on one beyond the creek, erosion control by contour strip cropping and diversion ditches has been started.

PLATE 22A. Sample of detailed conservation survey map from Triassic Upland illustrating influence of natural drainage on the pattern of soils. Soil, slope and erosion boundaries are shown by solid lines and areas are identified by symbols. First number in compound symbol is soil type.

Moderately deep, well drained soils: 66, Penn silt loam; 266, Penn loam; 366, Penn-Lansdale loams.

Shallow, well drained soils: 67, Penn shale loam.

Imperfectly drained upland soil: 72, Readington silt loam.

Poorly drained, upland soil: 73, Croton silt loam.

Slope is shown by letter: A, 0–3%; B, 3–8%; C, 8–15%; D, 15–25%.

Erosion is shown by the final number of the symbol: 0, no apparent erosion; +, recent deposition; 1, 0–25 per cent of surface soil lost; 17, 0–25 per cent of surface soil lost and occasional gullies; 2, 25–75 per cent of surface soil lost; 27, 25–75 per cent of surface soil lost and occasional gullies; 37, 75 per cent of surface soil to 25 per cent of subsoil lost and occasional gullies; 0, undifferentiated erosion.

Land use areas are bounded by dashed lines and land use is shown by letters standing alone, as follows: L, cropland; X, idle land; P, pasture; F, woodland; H, residential uses.

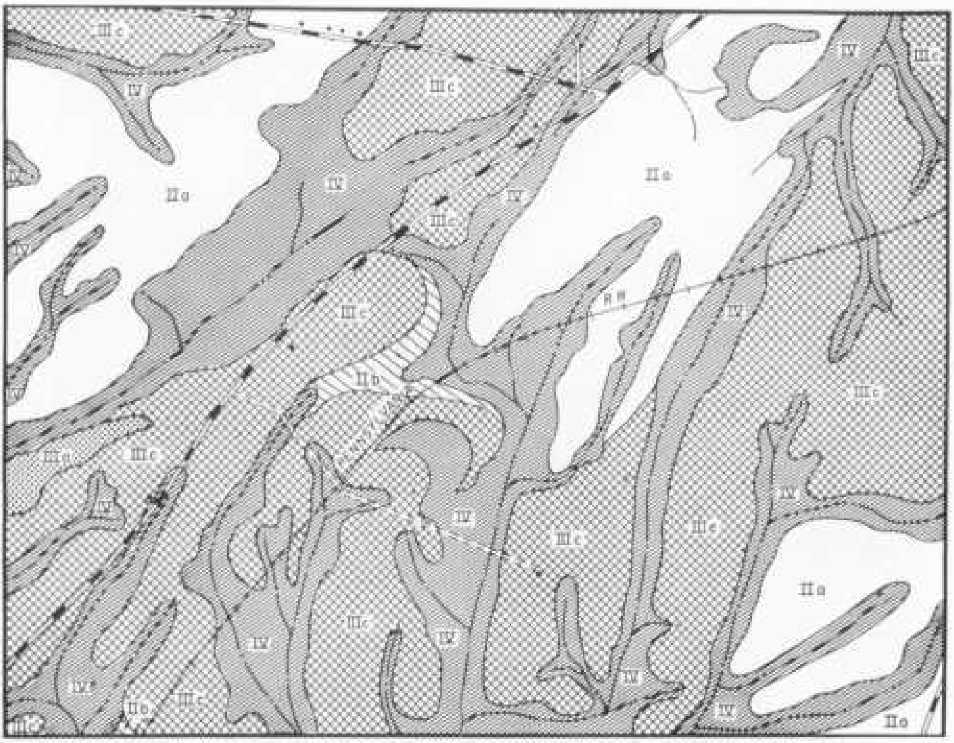

Plate 22B. Land use capability map for the same area as shown in plate 22A

Class IIa—Suitable for cultivation with simple soil and moisture conservation practices.

Class IIb—Suitable for cultivation with simple drainage practices.

Class IIIa—Suitable for cultivation with intensive soil and moisture conservation practices.

Class IIIc—Suitable for cultivation with intensive fertility and moisture conservation practices.

Class IV—Suitable for occasional or limited cultivation.

Note how the Class IV land generally corresponds to the poorly drained areas of the other map, but includes some steep land. The better crop-land is broken into small tracts by the branching areas of Class IV.

PLATE 23A. Aerial view of a section of the Frederick Valley near Walkersville shows intensive use of the limestone soil for cropland. The only woodland is along Monocacy River and on an island in the river. Nearly the entire area is a deep, well drained soil, the Duffield silt loam. There are minor areas of imperfectly drained soils. Although most of the area is on very gentle slopes there has been active erosion. One farm near the river has adopted soil conserving practices including contour strip cropping of sloping land which is further protected by diversion terraces.

PLATE 23B. Detailed conservation map of a block in the Appalachian Mountain Area showing the relation of cleared land to soil types and slope. Symbols show soil types, slope and erosion.

First number is soil type: 10, Worsham silt loam; 25, Eyler stony loam; 26, Eyler channery loam; 31, Harbaugh gravelly loam; 133, Codorus silt loam; 201, Rough stony land, Eyler-Catoctin soil material.

Letter is slope class. For stony soils: B, 5–10%; C, 10–20%; D, 20–35%; E, 35–40%; F is over 45%.

For non-stony soils: A, 0–3%; B, 3–8%; C, 8–15%; D, 15–25%.

Final number indicates erosion: 0, no apparent erosion; 1, 0–25 per cent of surface soil lost; 2, 25–75 per cent of surface soil lost; 27, 25–75 per cent of surface soil lost, and occasional gullies 37, 75 per cent of surface soil to 25 per cent of subsoil lost and occasional gullies.

Cropland is limited to the non-stony soils except for one area of a stony type from which part of the stones have been removed.

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