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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGY OF THE HANOVER-YORK DISTRICT PENNSYLVANIA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 204

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ILLUSTRATIONS

ABSTRACT

The Hanover-York district includes the Hanover and York quadrangles and the Pennsylvania portion of the Westminster and Parkton quadrangles. The district is in York County except a narrow area in Adams County on the western edge of the Hanover quadrangle. The largest cities are York, the county seat of York County, an industrial city of about 75,00 inhabitants near the north edge of the district; and Hanover, near the southwest border. Both cities are located in the southwestward-trending Hanover-York Valley, which crosses the district. This synclinal valley is underlain by Lower Cambrian and Ordovician (?) limestones and dolomites from which is derived most of the mineral wealth of the district. The valley is bordered on the northwest by the Hellam and Pigeon Hills, anticlinal uplifts that expose pre-Cambrian volcanic rocks and overlying Lower Cambrian conglomerates, quartzites, and phyllites. The Pigeon Hills, which attain an altitude of 1,220 feet, are the highest land of the area. Lower Cambrian arenaceous rocks are about 2,000 feet thick in anticlines north of the Hanover-York Valley. Other anticlines of these Lower Cambrian rocks lie south of the valley, but the conglomerate beds near the base are exposed only near Mount Pisgah. The Chickies quartzite, which is a white quartzite north of the valley, changes to a slate facies with thin quartzite beds south of the valley. The anticlines of Lower Cambrian arenaceous rocks plunge eastward into the East Prospect syncline, a valley on the eastern edge of the district underlain by Lower Cambrian and Ordovician (?) limestones. The valley continues eastward into the wide Lancaster Valley.

Triassic rocks, largely red sandstones and shales, cover the northwestern part of the Hanover quadrangle and form an upland of low relief, which is part of the Gettysburg Plain. The basal beds overlap the limestones of the York Valley and older rocks on the north side of the Pigeon Hills and dip gently northwestward. A diabase sill and diabase dikes cut the Triassic sedimentary rocks and also the older rocks to the southeast.

The lower Paleozoic limestones with the underlying arenaceous rocks are a part of the Paleozoic carbonate sequence of the Great Valley. The Lower Cambrian limestone and dolomite in the Hanover-York district is a fossiliferous series of beds equivalent to the Tomstown dolomite of the Great Valley, and belongs to a different sedimentary facies that was deposited in the southeastern part of the main Appalachian geosyncline.

The lower Paleozoic strata and the underlying pre-Cambrian rocks are closely folded and broken by thrust faults along which movement was northwestward. The southern anticline of the Pigeon Hills was thrust across the northern anticline, the movement taking place on the Gnatstown thrust fault, which extends along the valley eastward to York. A restudy of the structure of the Hellam Hills in the Middletown quadrangle has shown that the Highmount and Glades overthrusts of that area, which extend into the York and Hanover quadrangles, are thrust faults, and that remnants of the eroded Glades thrust block lie on limestones of the valley northwest of York.

The Stoner overthrust on the south side of the Hanover-York Valley in large part has overridden the Strickler anticline in the northeastern part of the district and has cut off minor folds in the syncline to the southwest.

Normal transverse faults trending north to northwest offset the basal beds of the Triassic sedimentary rocks and are, therefore, of Triassic age. Related normal faults are probably also Triassic. Other normal faults break up the Glades overthrust block but do not affect the Triassic rocks. Such faults are believed to be pre-Triassic and to have resulted from the fragmentation of the moving thrust block.

The southeastern part of the district, which lies southeast of the closely folded lower Paleozoic limestones and dolomites, is an upland area containing crystalline schists of the Glenarm series. The schists are largely argillaceous and arenaceous in character and include mica schist, quartzite, volcanic flows and tuffs, and some marble. These rocks are not lithologically equivalent to the lower Paleozoic limestones and dolomites, and the contact between the two series is one of discordance caused by faulting along the Martic overthrust. No fossils have been found in the schists, and they are assigned a probable pre-Cambrian age.

The schists are described in detail, and thin sections of them are illustrated. Folding and metamorphism took place over a long period and metamorphism is of variable intensity in different parts of the Martic overthrust block. The metamorphism is largely paracrystalline with the folding and, in part, outlasted it. Recumbent folds are observable in the schists, especially in the vicinity of the Tucquan anticline, which crosses the southeastern part of the district. The most prominent structure, however, is the foliation, which resulted from the shearing out of the closely packed recumbent folds. Consequently, the present superposition of layers is not a stratigraphic succession. The recumbent folds may reflect, on a small scale, a large recumbent fold developed during the movement that superposed the Glenarm series on rocks of known Paleozoic age; and the displacement may have taken place by a large-scale recumbent fold. The foliation resulting from the shearing out of earlier folds has been deformed by the latest compression, which has folded both the rocks of the Glenarm series and the overridden Paleozoic rocks lying to the northwest. This folding is known to be post-Beekmantown in age and is probably late Paleozoic.

The chief mineral resource of the district is limestone, which is obtained from many large quarries in the valley near York and Thomasville and is burned for lime, ground for agricultural use, or crushed for road material and concrete. Clay derived from the weathering of impure limestone is used for brickmaking, and sand is dug for local building purposes.

GEOLOGY OF THE HANOVER-YORK DISTRICT, PENNSYLVANIA

By ANNA JONAS STOSE and GEORGE W. STOSE

INTRODUCTION

LOCATION OF THE AREA

The area covered by this report embraces the Hanover and York quadrangles in southern Pennsylvania, between parallels 39°45′ and 40° and meridians 76°30′ and 77°, and includes also a narrow belt 2 miles wide just north of the Maryland line in the Westminster and Parkton quadrangles, which lie directly south of the Hanover and York quadrangles respectively. The area therefore is referred to as the Hanover-York district. The greater part of the area is in York County, and about 20 square miles along the west side of the Hanover quadrangle is in Adams County. (See fig. 1.)

York and Hanover are the largest towns in the district. The city of York, the county seat of York County, was founded in 1741, and in 1777 was the temporary seat of the Continental Congress. It is now an industrial city of about 75,000 inhabitants. Hanover, also a city that dates back to colonial times, is at the southwest end of the York-Hanover Valley. The population of Greater York was nearly 75,000 in 1940.[1] The population of the boroughs of West York and North York and of Spring Garden and parts of West Manchester and Springettsburg Townships are included in this figure. The population of the city of York in 1940 was 56,712, and that of Hanover was 13,076. Other towns and villages in order of population are: Red Lion 4,891; Dallastown, 2,917; Glen Rock, 1,412; Spring Grove, 1,259; Windsor, 1,108; Stewartstown, 985; Shrewsburg, 720; Yoe, 528; and Jefferson, 400. The population of many other villages is less than 500.

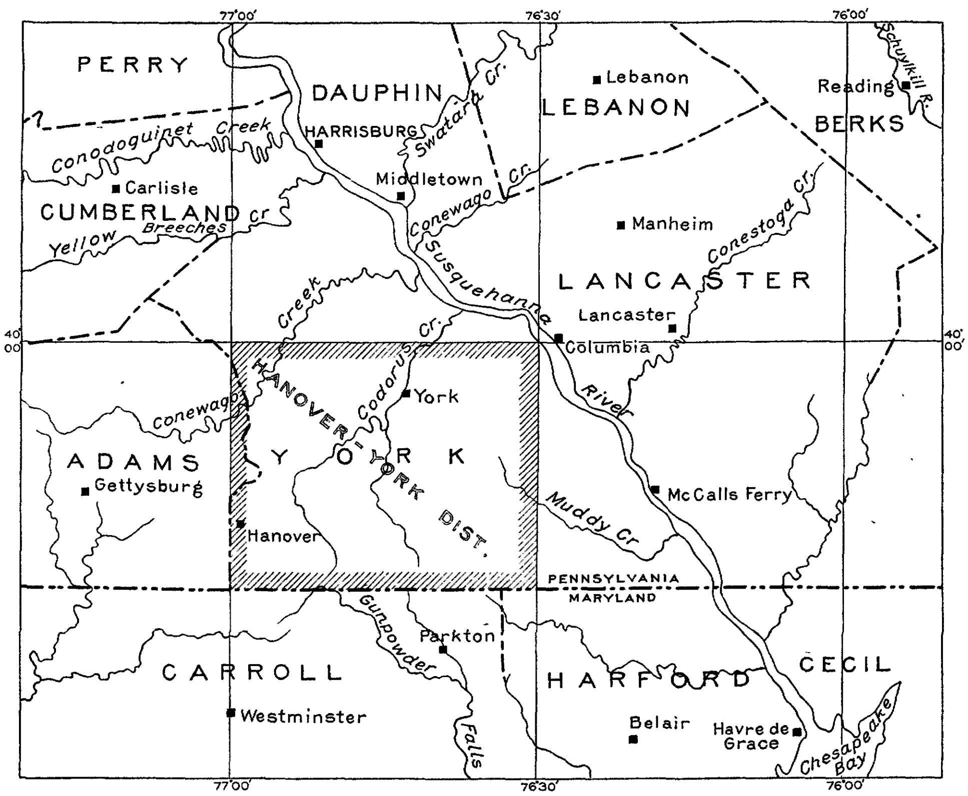


FIGURE 1.—Index map of southern Pennsylvania and adjacent part of Maryland, showing location of the Hanover-York district.

[1] Information on population was furnished by the Chamber of Commerce, York, Pa.

The central part of the area is crossed by the Baltimore and Harrisburg division of the Pennsylvania Railroad, which follows Codorus Creek to and north of York. A branch extends east of York to Lancaster and another runs southwest to Hanover and Gettysburg, with a branch by way of Littlestown to Frederick, Md. The Western Maryland Railroad extends from York through Spring Grove to Hanover and has a branch line up the West Branch of Codorus Creek into Maryland. A bus line runs along the valley from York to Wrightsville, and an electric railway runs from York to Spring Grove and to Hanover.

PREVIOUS WORK

The earliest geologic work in the Hanover-York district was that of the First and Second Geological Surveys of Pennsylvania. The results were published in reports on York and Adams Counties. In reports of the Second Geological Survey Lesley and Frazer termed the rocks, older than the limestone, gneiss, hydromica schist, phyllite, slate, and Cambrian quartzite. The limestone was called Silurio-Cambrian, and the Triassic rocks lying northwest of these older rocks were recognized as "New Red" sandstones. Walcott [2] reviewed the earlier work of the Pennsylvania Geological Survey and described Lower Cambrian fossils in the quartzite 4 miles northwest of York and in limestone at several localities in and near York.[3] Most of his fossil localities in limestones are now covered by York city development. Walcott concluded that, excepting the Mesozoic sandstone, no rock in York County is younger than Lower Cambrian.

FIELD WORK BY THE WRITERS AND ACKNOWLEDGMENTS

Field work on the area here described was started in 1920 when the authors made a reconnaissance of the valley limestones from Hanover to Quarryville in order to establish the lower Paleozoic section of the region and to correlate the formations of the Hanover Valley west of Hanover in the Gettysburg quadrangle with those in the valley to the east. The area was mapped in detail during parts of the field seasons from 1922–37. The work was done in cooperation with the Pennsylvania Topographic and Geologic Survey, G. W. Stose representing the Federal Survey and Anna Jonas Stose the State. Previously published reports on quadrangles to the east, north, and west of the Hanover-York district are as follows:

Jonas, A. I., and Stose, G. W., Geology and mineral resources of the New Holland quadrangle, Pa.: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas, No. 178, 1926. Geology and mineral resources of the Lancaster quadrangle, Pa.: Idem, No. 168, 1930.

Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district, Pa.: U. S. Geol. Survey Bull. 799, 1929.

Stose, G. W., Geology and mineral resources of Adams County, Pa.: Pennsylvania Topog. and Geol. Survey Bull. C–1, 1932.

Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle: U. S. Geol. Survey Bull. 840, 1933; Geology and mineral resources of York County, Pa.: Topog. and Geol. Survey Bull. C–67, 1939.

Although both authors covered the entire area in the field, the writing of parts of the report was divided. Anna J. Stose wrote the part relating to the pre-Cambrian rocks, the rocks of the Martic overthrust block, and their structure, while G. W. Stose wrote most of the geology and structure of the Paleozoic and the Triassic sedimentary rocks and prepared most of the accompanying structural diagrams.

The writers wish to express thanks to K. E. Lohman, of the Geological Survey, for the photomicrographs figured in this report; to C. E. Resser, of the U. S. National Museum, for determination of the fossils; and to E. B. Knopf, of the Geological Survey, for assistance and helpful suggestions on the metamorphic and structural problems of the Martic overthrust block and of the adjoining metamorphosed Paleozoic rocks. The photographs, except those of polished rock specimens, which were made in the photographic laboratory of the Geological Survey, are by G. W. Stose.

SURFACE FEATURES

SURFACE FORMS AND ALTITUDE

The Hanover-York district is part of the physiographic division of the eastern United States known as the Piedmont province. (See fig. 2.) The surface forms are of four distinct types: (1) A well-dissected upland in the southeastern part of the area; (2) The Hanover-York Valley, a narrow lowland that diagonally crosses the area; (3) High hills and peaks that form the Pigeon Hills and the southern part of the Hellam Hills; (4) A dissected low upland northwest of the Pigeon Hills, part of the Gettysburg Plain.

The southeastern upland covers about two-thirds of the Hanover-York district. (See pl. 1.) It includes parts of four drainage basins, the largest of which drains northwestward by the three main branches of Codorus Creek and a large tributary, Mill Creek. East of this basin in the eastern part of the York quadrangle the upland is drained eastward chiefly by Muddy Creek. Many lateral branches of these major streams run northeast and southwest and give rise to a poorly developed trellised drainage pattern,

[2] Walcott, C. D., The Cambrian rocks of Pennsylvania: U. S. Geol. Survey Bull. 134, pp. 9–19, 1896.
[3] Idem., pp. 17–18.

The highest part of the southeastern upland forms an irregular ridge which crosses the central part of the York quadrangle and passes through Red Lion, Rinely, Shrewsbury, and south of New Freedom. In the vicinity of Red Lion, the summit of the ridge is over 900 feet above sea level and attains 1,000 feet at a point east of Yoe. The divide is mostly below 900 feet from Red Lion to Winterstown; but southward as far as Shrewsbury it is broader and more than 1,000 feet in altitude. At Mount Olivet Church one sharp hill attains an altitude of 1,080 feet. South of Rinely the trend of the central divide changes from southerly to westerly and slightly lower ridges. From Huntrick Hill southwest to West Manheim, the dissected upland from 900 to 1,000 feet in altitude reaches 1,100 feet near Wentz in Carroll County, Md. These hills are capped by quartzites which control their direction and height.

The southeastern upland as a whole slopes northwestward to the Hanover-York Valley where it terminates abruptly at altitudes between 700 and 900 feet along a line that trends northeastward parallel to the rock structures.

The Hanover-York Valley crosses the northwest third of the area, extending from its northeast border

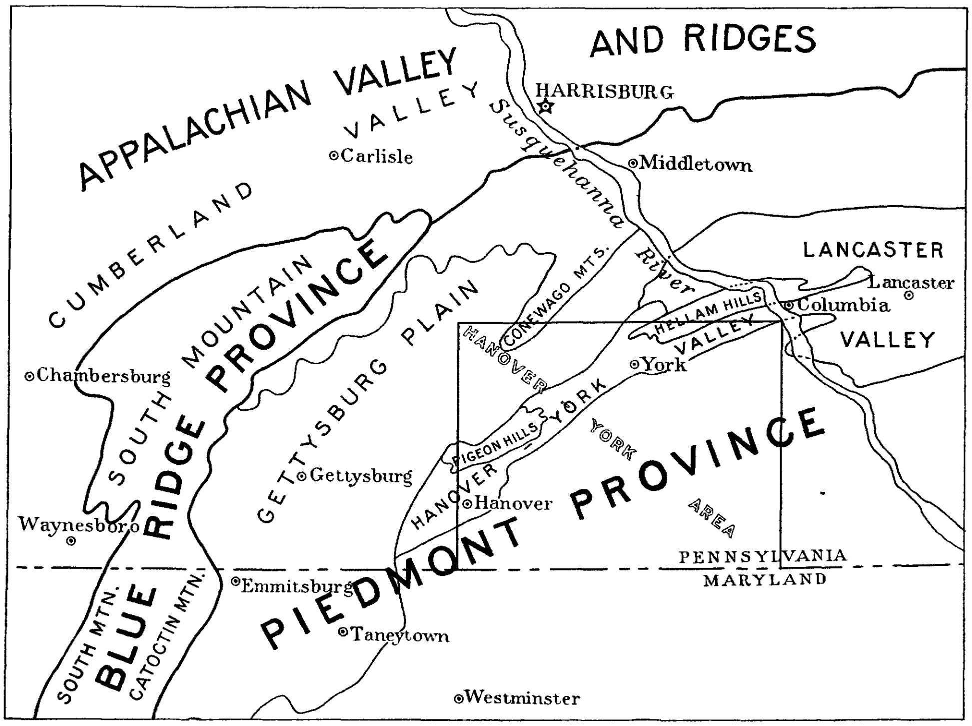


FIGURE 2.—Sketch map showing physiographic divisions in southern Pennsylvania and adjacent part of Maryland.

southwesterly, and the westward-trending part separates the headwaters of Codorus Creek, which flows northward, from those of Deer Creek and Gunpowder Falls and its tributaries, which flow southeastward. The Harrisburg division of the Pennsylvania Railroad crosses the divide at Summit Grove through a low gap at an altitude of 840 feet.

In the York quadrangle the northward-trending part of this central divide crosses the structures of the crystalline schists; and, except locally, as north of Red Lion where the 1,000-foot hill is developed on quartzite, the location of the divide is not the result of greater hardness of the underlying rocks. West of the valley of South Branch of Codorous Creek, a series of parallel ridges trending southwestward has a general elevation of 1,000 to 1,100 feet. Rocky Ridge, the highest point in the southeastern upland, is underlain by the Wissahickon formation and parallels Dug Hill and other

southwestward through York and Hanover. The valley is in limestone, and northeast of York is about 2 miles wide, and its floor is about 420 feet in altitude. A tributary of Kreutz Creek has cut a secondary valley in the floor near Hellam Station and Codorus Creek crosses the valley at York. To the southwest and as far as Nashville at the northeast end of the Pigeon Hills, the valley increases in width to about 4 miles. In this wider part many low hills of shale rise above the valley to altitudes of more than 500 feet. This part of the valley merges northwestward with the Triassic upland of the northwestern part of the Hanover quadrangle.

Between the Pigeon Hills and the southeastern upland southwest of Nashville the valley is constricted to a width of 2 miles, and expands again to a width of 4 miles in the vicinity of Hanover where it is nearly flat and has an altitude of about 600 feet. The valley floor, therefore, rises southwestward, away from the Susquehanna River.

The lowest point in the Hanover-York district is not in the Hanover-York Valley but in a valley also with a limestone floor in the southern upland. There Canadochly Creek has cut down to an altitude of 240 feet and at this point is only a quarter of a mile from its mouth at the Susquehanna River. The highest point in the district is in the Pigeon Hills, which rise as much as 600 feet above the limestone valley at Hanover, have a general altitude between 1,000 and 1,100 feet, and attain a maximum of 1,240 feet. The Pigeon Hills die out at Nashville, where the hard Cambrian quartzites that form them plunge under softer, overlying rocks. A similar line of hills northeast of York is the southwest end of the Hellam Hills, most of which are in the Middletown quadrangle north of the York quadrangle.

A low upland or dissected low plateau, which is a part of the Gettysburg Plain, lies northwest of the Pigeon Hills and that part of the Hanover-York Valley between York and Nashville. It coincides with the area of outcrop of the Triassic rocks in the northwestern part of the Hanover quadrangle. Most of the low ridges on this upland trend northeastward; but Conewago and Little Conewago Creeks, which cross the low plateau, have not developed a systematic dissection because the Triassic beds are not hard enough to control the erosion. The average height of this upland is 500 feet above sea level, but it increases to 600 feet in the extreme northwest corner.

DRAINAGE

The Hanover-York district is drained principally by Codorus, Muddy, Fishing, and Conewago Creeks, which flow into the Susquehanna River. In the southern part are the headwaters of a few streams that flow south into Chesapeake Bay. Codorus Creek with its East, South, and West Branches drains most of the central part of the area south of the Pigeon Hill divide and west of a main divide, which extends southward irregularly across the central part of the York quadrangle. South and West Branches rise near Summit and West Manheim, and East Branch rises south of Shrewsbury just north of the Maryland State line. These three branches join a few miles south of York to form Codorus Creek, which flows north through the city and empties into the Susquehanna River 5 miles north of the district. Mill Creek, another large tributary, joins the main stream north of York.

Fishing Creek and North and South Branch of Muddy Creek head in the southeastern upland east of the main divide and drain eastward and southeastward directly into the Susquehanna River. The upper reaches of Kreutz, Cabin, and Canadochly Creeks, smaller tributaries to the Susquehanna, drain the northeastern part of the district. Kreutz Creek and its West Branch drain the eastern end of the York Valley. Deer Creek heads in the southern part of the York quadrangle, flows southeast across Maryland, and empties into the Susquehanna River. The headwaters of Gunpowder Falls and Beetree Run rise on the south side of the Shrewsbury divide and drain southward into the Gunpowder Falls, a part of the Chesapeake drainage system.

Headwaters of Conewago Creek drain the southwest corner of the district. North of the Pigeon Hills the creek re-enters the northwestern part of the area and flows across it for 8 miles. Little Conewago Creek rises on the north slope of the Pigeon Hills, flows northeastward across the northern part of the Hanover quadrangle, and joins Conewago Creek in the Middletown quadrangle not far from the border of the district.

AREAL GEOLOGY

GENERAL FEATURES

The rocks of the Hanover-York district (pl. 1) comprise pre-Cambrian crystalline rocks of both igneous and sedimentary origin, lower Paleozoic sedimentary rocks, and Triassic rocks, both sedimentary and intrusive. Quaternary alluvium and gravel are also present along most of the larger streams.

The Triassic rocks form the surface of the northwestern part of the Hanover quadrangle. They consist of red or gray conglomerate, sandstone, and shale intruded by diabase dikes and the Gettysburg diabase sill. Triassic dikes penetrate also the older rocks to the southeast. The Triassic sedimentary rocks overlie unconformably the Cambrian and pre-Cambrian rocks exposed southeast of them.

The Paleozoic and pre-Cambrian rocks belong to two belts. The northwestern belt is northwest of the Martic overthrust and contains folded pre-Cambrian volcanic rocks, Lower Cambrian siliceous rocks, and lower Paleozoic limestones. The pre-Cambrian rocks are exposed in two anticlinal areas—the Pigeon Hills anticlinorium, north of Hanover, and the Mount Zion anticline, which forms the southwest end of the Hellam anticlinorium. These pre-Cambrian rocks are overlain unconformably by Lower Cambrian conglomerate, quartzite, slate, and phyllite, followed by Lower Cambrian limestones and the Conestoga limestone, in which the Hanover-York Valley was formed. On the south side of the York Valley, the Antietam quartzite of the Cambrian system comes to the surface on the northwest limb of the Strickler anticline, which is largely covered in this area by the Stoner overthrust block. Lower Cambrian arenaceous rocks form most of the Stoner block and are exposed in the Mount Pisgah, Kraft Mill, and Holts anticlines. These arenaceous rocks are of a facies somewhat different from the Lower Cambrian rocks exposed north of York Valley. They are overlain by lower

Paleozoic limestones in the East Prospect and Jefferson synclines adjacent to the Martic overthrust.

These anticlines and synclines are structurally part of the Honeybrook uplift to the northeast and of the Catoctin Mountain-Blue Ridge anticlinorium to the southwest, from which they are separated for a distance of 20 miles by Triassic sedimentary rocks. (See fig. 26.) In southern Pennsylvania the Triassic belt trends across the strike of the Paleozoic structures, and separates the Pigeon Hills anticline from the anticlines of pre-Cambrian and Lower Cambrian rocks in South Mountain in the Fairfield and Gettysburg quadrangles.[4] This belt of Triassic rocks also separates the Hanover Valley from the Frederick Valley of Maryland in which Antietam quartzite and overlying Upper Cambrian and Lower Ordovician limestones are exposed.

The southeastern belt consists of rocks of the Martic overthrust block, which occupies the southeastern part of the district. The northwest boundary of the Martic overthrust block extends southwestward from a point 1 mile south of East Prospect to the southwest corner of the district. The rocks of the Martic overthrust block are closely folded crystalline schists of probable pre-Cambrian age. At the northwest they comprise the Marburg schist and associated quartzites, and farther southeast they are the albite-chlorite schist facies of the Wissahickon formation, the Wakefield marble, metabasalt flows, and metamorphosed tuffs and phyllites.

The pre-Triassic rocks of the northwestern belt, including pre-Cambrian rocks of the Pigeon Hills and overlying Paleozoic sedimentary rocks, are described first, the rocks of the Martic overthrust block next, and the Triassic rocks last.

PRE-CAMBRIAN ROCKS OF THE PIGEON HILLS

GENERAL DESCRIPTION

The pre-Cambrian rocks of the Pigeon Hills are metamorphosed volcanic rocks and are exposed in two anticlines southeast of Abbottstown. The southernmost exposure, which is in the Gnatstown anticline, is very small. Together with the overlying basal Cambrian beds, it is thrust northward along the Gnatstown overthrust onto Lower Cambrian rocks of the High Rock anticline. The northern exposure extends 4 miles along the strike in the High Rock anticline and has a maximum width of 1¼ miles. Basal Triassic sedimentary rocks overlap the north side of these older rocks for 3 miles. Most of the volcanic rocks are green, massive, amygdaloidal metabasalt. Blue slates containing flattened green amygdules occur in some places in the metabasalt. The slates may be metamorphosed andesite or rhyolite tuff but were not mapped separately. Similar volcanic slates and porphyritic aporhyolite are exposed in the Hellam Hills.[5]

The floor upon which these lavas were poured out is not exposed in the Pigeon Hills and Hellam Hills nor in the Catoctin Mountain-Blue Ridge anticlinorium farther southwest in Pennsylvania and northern Maryland, where volcanic rocks likewise form the pre-Cambrian core of the uplift as far south as Middletown, Md. In the Catoctin Mountain-Blue Ridge anticlinorium south from Middletown and across Potomac River in Virginia, volcanic rocks border the uplift and the floor upon which the volcanic rocks were poured out is exposed in the center of the anticlinorium. This floor consists of an injection complex of earlier pre-Cambrian age. The rocks, beginning with the oldest, are mica schist and gneiss, hornblende diorite, intrusive granites, porphyritic augen gneiss, injection gneiss, and migmatite which formed by the injection of granitic intrusives in the older mica schist and hornblende diorite. This group of rocks is much older than the pre-Cambrian volcanic rocks which once covered it in the center of the uplift as well as on the limbs of the anticlines where they are now preserved. The age relation of the two pre-Cambrian series and their extent in Maryland and Virginia have been briefly described by the authors[6] of this report. The evidence that the volcanic flows are younger than the injection complex is briefly as follows: (1) So far as is known by the writers, the granitic intrusive rocks of the Catoctin Mountain-Blue Ridge anticlinorium do not penetrate the volcanic series. (2) The metadiabase dikes, which the writers regard as syngenetic with the metabasalt, crosscut the intrusive rocks and gneisses, bevel their structures, and show chilled margins and sharp contacts with the older rocks. (3) The granitic intrusions were contemporaneous with the folding, and these processes together with the resulting thermal metamorphism produced the effects now seen in rocks of the injection complex; whereas the overlying volcanic flows, which are little metamorphosed except where they were involved in Paleozoic orogeny, were not affected by the granitic intrusion and accompanying metamorphism and obviously were extruded at some later time. (4) At many places in Virginia arkose, conglomerate, and volcanic breccia containing pebbles and angular blocks of granite and diorite lie at the base of the volcanic series and overlie the injection complex.

METABASALT

Metabasalt is a massive green rock, often called greenstone, composed of feldspar, epidote, hornblende, chlo-

[4] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), p. 4, 1929.

[5] Jonas, A. I., and Stose, G. W.: Geology and Mineral Resources of the Middletown quadrangle, Pa., U. S. Geol. Survey Bull. 840, pp. 9–12, 1933.

[6] Jonas, Anna I., and Stose, G. W., Age relations of the pre-Cambrian rocks in the Catoctin Mountain-Blue Ridge and Mount Rogers anticlinoria in Virginia: Am. Jour. Sci., 5th ser., vol. 237, pp. 575–593, 1939.

rite, quartz, and magnetite. It is spotted with light-green or white amygdules containing either epidote or quartz, or both minerals. The amygdules may weather in relief and stand out as knots on the surface or may dissolve leaving a pitted or porous rock. The rock has been replaced in part by epidote and quartz and is cut by veins of these minerals.

Thin sections show that the massive greenstone has a groundmass of albite, epidote, quartz, and magnetite, and contain phenocrysts of feldspar and the green hornblende, uralite, some of which show a core of original augite. The amygdules contain hornblende, epidote, calcite, quartz, chlorite, and albite. The albite feldspar of the groundmass is corroded by secondary hornblende and chlorite and is itself secondary to more calcic feldspar, some of whose lime went to form the epidote.

No analyses of the metabasalt of the Pigeon Hills are available but the following analysis is of rock from the pre-Cambrian of South Mountain, Adams County, Pa., an area that was probably continuous with the Pigeon Hills in pre-Cambrian time.

Analysis of metabasalt from Bechtel copper shaft, South Mountain[7]

SiO_2	41.280
Al_2O_3	18.480
Fe_2O_3	9.440
FeO	8.200
CaO	7.040
MgO	7.486
Na_2O	3.523
K_2O	2.208
Ign	2.740
	100.397

VOLCANIC SLATE

Blue spotted slate is associated with the metabasalt in the Pigeon Hills. The bluish-gray sparkling, sericitic slate contains some flattened amygdules. In places it is banded with green chlorite. Under the microscope the bulk of the rock is seen to be sericite and ilmenite or iron oxide dust. The original rock was probably an andesite or rhyolite tuff. Slate having similar constituents and associations is widespread in Carroll and Frederick Counties, Md., and analyses[8] show that these slates are low in silica (45.80 percent) for a rhyolite, and low in lime (1.15 to 1.77 percent) for an andesite. The iron oxide content is high (11.73 to 26.91 percent). Although TiO_2 is not given in the analyses, it is usually present in these volcanic slates.

AGE OF THE VOLCANIC ROCKS

The volcanic rocks of the Pigeon Hills in the Hanover quadrangle are pre-Cambrian because they are overlain unconformably by basal Lower Cambrian sedimentary rocks. In the Pigeon Hills the metabasalt and blue tuffaceous slate appear to be interbedded, but outcrops are not sufficiently good to prove this relationship. It is known that in the Catoctin Mountain and South Mountain areas the rhyolite flows associated with tuffaceous slate are older than the basaltic lavas.[9]

PALEOZOIC SEDIMENTARY ROCKS NORTH OF THE MARTIC OVERTHRUST

The sedimentary rocks of Paleozoic age cross the area in a belt about eight miles wide between the Triassic rocks on the northwest and the Martic overthrust on the southeast. They comprise Lower Cambrian conglomerates, quartzites, and phyllites in the Pigeon Hills and Mount Zion Hill; limestones, dolomites, and slates of Lower Cambrian age and argillaceous crystalline limestone and limestone conglomerates of Ordovician (?) age in the Hanover-York Valley; and Lower Cambrian slates with thinner quartzite beds and phyllites in the low hills south of the valley. The names, thicknesses, and summary description of the rocks are given in the accompanying columnar section (fig. 3).

CAMBRIAN SYSTEM

In ascending order, the rocks of the Cambrian system in this area are the Chickies quartzite with the basal Hellam conglomerate member, Harpers phyllite, Antietam quartzite, Vintage dolomite, Kinzers formation, and Ledger dolomite, all of Lower Cambian age.

CHICKIES QUARTZITE NORTH OF THE HANOVER-YORK VALLEY

NAME AND DISTRIBUTION

The Chickies quartzite is the oldest of the Lower Cambrian formations exposed in this area. It unconformably overlies volcanic rocks of pre-Cambrian age. The name Chickies quartzite was applied by Lesley and Frazer in 1878 to the quartzites that make Chickies Rock, a cliff on the east side of Susquehanna River, 1½ miles north of Columbia. In York County the rocks to which this name is applied are a direct continuation of the quartzite at Chickies Rock across the river, but include a thick basal conglomerate member, named Hellam, not exposed east of the river. The Hellam conglomerate member takes its name from the Hellam Hills, in York County, where the conglomerate is best developed.

The Chickies quartzite forms the higher parts of the Pigeon Hills north of Hanover and of the Hellam Hills northeast of York. In the area south of the Hanover-York Valley, its representative has a different litho-

[7] Henderson, C. H., The copper deposits of the South Mountain, Pa.: Amer. Inst. Min. Eng. Trans., vol. 12, p. 82, 1884.

[8] Mathews, E. B., and Grasty, J. S., Report on the limestones of Maryland: Maryland Geol. Survey, vol. 8, pp. 370, 378, 1909.

[9] Keith, Arthur, Geology of the Catoctin belt; U. S. Geol. Survey 14th Ann. Rept., pt. 2, pp. 309–311, 1894. Bascom, Florence, The ancient volcanic rocks of South Mountain, Pa.; U. S. Geol. Survey Bull. 136, p. 30, 1896. Stose, G. W., Mineral resources of Adams County, Pa.: Pennsylvania Topo. and Geol. Survey Bull. C–1, p. 9, 1929; U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), p. 4, 1929.

Age	Formation	Symbol	Thickness (feet)	Description
Triassic.	Gettysburg shale with Conewago conglomerate member.	TRg TRcw	2,000+	Red sandstone and shale; thick hard conglomeratic quartzite in lower part of formation, Conewago conglomerate member.
	New Oxford formation with conglomerate at and near base.	TRno TRc	6,000±	Red shale and sandstone with interbedded gray to yellow arkosic sandstones; quartzose conglomerate locally at base.
	-Unconformity-			
Ordovician(?).	Conestoga limestone.	Oc	300–1,000	Thin-bedded blue limestone with many argillaceous partings; thick sandy limestone conglomerates in lower part. In part may be of Cambrian age.
	-Unconformity-			
Cambrian.	Ledger dolomite.	Єl	1,200±	Massive granular gray dolomite, little bedded; weathers to dark-red soil.
	Kinzers formation.	Єk	160–400	Dark shale below; thick marble and limestone conglomerate above.
	Vintage dolomite.	Єv	500–800	Dark-blue knotty dolomite.
	Antietam quartzite.	Єa	100–200	White ferruginous granular quartzite.
	Harpers phyllite.	Єhp	800–1,000	Gray-green phyllite and banded slate, with thin quartzites.
	Chickies quartzite with Hellam conglomerate member.	Єc Єh	400–900	Massive quartzite, with basal conglomeratic quartzite and slate; 500 feet thick in Hellam Hills.
Pre-Camb.	Metabasalt.	mb		Altered basalt flows and tuffs.

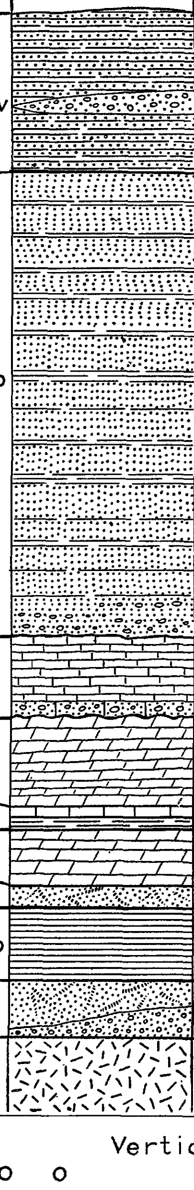


FIGURE 3.—Columnar section of sedimentary rocks north of the Martic overthrust in the Hanover-York district.

logic character and, therefore, is called the Chickies slate and is described separately.

The Chickies quartzite with its basal Hellam conglomerate member surrounds the core of pre-Cambrian metabasalt in the Pigeon Hills except where the Triassic beds overlap the northern edge of the metabasalt. The formation is here folded into two anticlines which extend for about seven miles along the strike. The quartzites in the southern, or Gnatstown, anticline make the southern part of the Pigeon Hills. The quartzites in the northern, or High Rock, anticline make High Rock and other high peaks, one of which has an altitude of 1,240 feet and is the highest point in the district. The two anticlines of Chickies quartzite plunge northeastward. The quartzite in the northern fold nearly reaches La Bott, and that in the southern fold extends to a point half a mile west of Nashville. At the southwest, the Chickies in both folds is greatly narrowed and broken by faults. The Hellam conglomeratic member predominates over the quartzite in the Pigeon Hills, where hard conglomeratic beds make all the high peaks and ridges. Stratigraphically lower beds of softer conglomerate and arkosic quartzite with black slate at the base are exposed in the cores of the anticlines and form the inner slopes of the ridges. The white *Scolithus*-bearing quartzite of the upper part of the Chickies formation makes the outer slopes. The lower division of the Hellam conglomerate member is separately mapped in the Pigeon Hills.

Northeast of York, the Chickies quartzite on Mount

Zion Hill, which is the southwest end of the Hellam Hills, extends only a short distance into the York quadrangle. This part of the hill is composed largely of the Hellam conglomerate member, only a small area at the western end near Condorus Creek being of the quartzite. Except two small exposures of quartzite, the Chickies is cut out by faulting on the south flank of the Mount Zion anticline.

CHARACTER AND THICKNESS

The Chickies quartzite at the type locality, Chickies Rock on Susquehanna River north of Columbia, is a massive well-bedded white vitreous quartzite. It contains the worm boring, called *Scolithus*, a small round silicified tube lying perpendicular to the bedding. The upper beds are coarser grained and arkosic and contain some black slate layers. The Hellam conglomerate member forms the base of the formation in the Hellam Hills west of the river but is not exposed at Chickies Rock. This member consists of quartzose conglomerate, arkosic quartzite, and interbedded dark slate. In the Hellam Hills, north of the York quadrangle, the Hellam member contains thick beds of coarse conglomerate, some layers of which are made up of rounded cobbles. (See pl. 2, *A* and *B*.) The conglomerates continue into Mount Zion Hill, in the York quadrangle, but the coarse cobble bed does not occur there.

In the Pigeon Hills the composition of the Chickies quartzite is similar to that in the Hellam Hills. The conglomerate beds are thicker but are not so coarse and have more interbedded quartzite. The slate at the base is mapped separately.

A continuous unbroken section of the formation is not present in the area, but a generalized section from the Hellam Hills in the Middletown quadrangle follows:

Generalized section of Chickies quartzite north of the York Valley

	Feet
Massive to thin-bedded hard white quartzite, containing numerous *Scolithus* tubes in lower and middle part and some dark slate and coarser granular quartzite in upper part	300–400
Hellam conglomerate member, composed of coarse- and fine-grained sericitic quartz conglomerate interbedded with white sericitic feldspathic quartzite, thin layers of green and purple banded quartzite, and blue and green slate	250–500±
	550–900±

The following detailed section of the upper part of the formation is in the vicinity of Chickies Rock:

Composite section of upper part of Chickies quartzite in vicinity of Chickies Rock

	Feet
Harpers phyllite: Grayish-green phyllite and slate.	
Chickies quartzite:	
Thin-bedded quartzite and interbedded thin dark slate	20±
Thin-bedded white quartzite and coarse, granular blue quartzite containing grains of blue and dark glassy quartz and feldspar and small pebbles	20±
White thin-bedded quartzite interbedded with thin dark slate	40±
Slate and thin beds of quartzite banded with slate	50±
Thin- and thick-bedded white sericitic quartzite containing *Scolithus* tubes; weathers to crumbly sandrock and white sericitic clay	15±
Thick-bedded vitreous white quartzite	20±
Thin-bedded vitreous white quartzite; beds generally less than 5 feet thick; contains many *Scolithus* tubes	100±
Very massive vitreous white quartzite; beds 20 feet thick (Base of Chickies quartzite not exposed)	70±
	335±

The section is confused by faulting and repetition of beds, as shown by sketch sections in the Middletown report.[10]

A section of the basal Hellam conglomerate member where it is thickest follows:

Composite section of Hellam conglomerate member along the river bluff west of Accomac

	Feet
Chickies quartzite: Thin-bedded *Scolithus*-bearing quartzite	200±
Hellam conglomerate member:	
Black slate	20±
Conglomerate and thick-bedded pebbly quartzite with sericitic quartzose matrix	40±
Concealed	100±
Purple-banded coarse-grained arkosic quartzite containing pebble and conglomerate beds; upper part covered	200±
Coarse cobble bed 5 feet thick, containing rounded 3-inch pebbles chiefly of white quartz, and finer pebbly purple arkosic quartzite	40±
Crumbly sericitic quartzite containing glassy quartz grains and scattered small pebbles of quartz	100±
	500±
Pre-Cambrian:	
Aporhyolite, cut by shear zone of pink aporhyolite breccia containing quartz, hematite, and epidote.	
Metabasalt.	

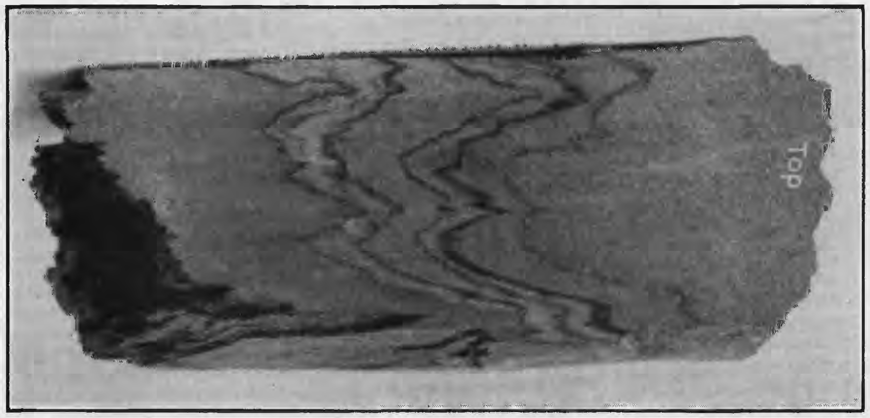
The coarse conglomerate bed is 5 feet thick and is composed of well-rounded cobbles 3 to 6 inches in diameter in a fine-grained quartz and sericite matrix which firmly cements the pebbles. The cobbles are mostly milky-white quartz and also include some red and black jasper and quartzite containing black hornblende needles. Some of the finer conglomerate beds are purple and green, having a dark-green quartz and sericite matrix which contains small pebbles of blue, pink, and clear glassy quartz, coarse grains of pink and white

[10] Stose, G. W., and Jonas, Anna I., Geology and mineral resources of the Middletown quadrangle, Pa.: U. S. Geol. Surv. Bull. 840, figs. 2 and 3, p. 13, 1933.

A. COBBLE BED IN HELLAM CONGLOMERATE MEMBER OF CHICKIES QUARTZITE AT HIGHMOUNT, MIDDLETOWN QUADRANGLE.

Rounded pebbles of milky and white quartz as much as 3 inches in size in fine-grained quartzose matrix.

B. FLAT-LYING COARSE PEBBLE BEDS IN HELLAM CONGLOMERATE MEMBER OF CHICKIES QUARTZITE, TOP OF MOUNT ZION RIDGE JUST NORTH OF THE YORK QUADRANGLE.



C. CLOSELY FOLDED CHICKIES SLATE, EAST BANK OF SUSQUEHANNA RIVER ABOUT 1½ MILES SOUTH OF COLUMBIA.

Sericitic quartzose beds (light) banded by dark slate and cut by vertical cleavage.

D. EROSION REMNANT OF QUARTZITE BEDS IN CHICKIES SLATE FORMING ROCK PINNACLE IN FLOODPLAIN OF CODORUS CREEK NEAR BRILLHART.

Preserves crest of an anticline.

feldspar, and some angular fragments of green quartzite. At the base in some sections are thin beds of shiny green or blue slate, some interbedded fine quartzose layers, finely banded magnetite-bearing quartzite with glassy quartz grains and green and black slaty bands 2 inches thick.

The upper part of the Chickies quartzite is well exposed in quarries and in the banks of Codorus Creek at the west end of Mount Zion Hill in the York quadrangle (fig. 4) where the following section occurs:

Section of upper part of the Chickies quartzite at west end of Mount Zion Hill, along Codorus Creek

	Feet
Harpers phyllite: Sandy phyllite with quartzose layers; chiefly west of creek.	
Chickies quartzite:	
Thin-bedded crumbly quartzite, quarried for sand in Elmer B. King & Bro. quarry; many *Scolithus* tubes in the quartzite; some beds have purplish tint and all weather rusty. Upper bed, 3 feet thick, of hard quartzite having rough bedding surfaces and laminated by cross bedding; weathers light buff	120±
Thick-bedded vitreous quartzite; *Scolithus* in upper beds	80±
Hellam conglomerate member:	
Black and white, banded slate and thin beds of gray to green and dark, banded argillaceous quartzite; 3-foot bed of granular quartzite and some fine quartz conglomerate near the base	200±
Thick white, rusty-weathering, feldspathic quartzite; coarse-grained, rust-specked quartzite to fine conglomerate containing small dark shale pebbles. Base not exposed	20±
	420±

The black and white slate is exposed in the river bluff east of the bridge of the Pennsylvania Railroad across Codorus Creek, on the upland to the southeast, and on the road crossing the hill to Pleasureville. It is also exposed in the lowland northeast of Pleasureville, in the Middletown quadrangle. (See fig. 4.)

The Hellam conglomerate member is exposed on Mount Zion Hill in the northern part of the York quadrangle and adjacent part of the Middletown quadrangle, but the sequence of beds and their thickness are difficult to determine. A composite section with approximate thicknesses is as follows:

Composite section of Hellam conglomerate on Mount Zion Hill

	Feet
Chickies quartzite:	
Hard vitreous *Scolithus*-bearing quartzite.	
Hellam conglomerate member:	
Black and white, banded slate and thin quartzite beds	200±
Hard, granular feldspathic to vitreous, white quartzite, current-bedded in part	20±
Argillaceous and ferruginous, banded arkosic pebbly quartzite	100±
Chickies quartzite—Continued.	
Hellam conglomerate member—Continued.	
Arkosic quartzite containing scattered pebbles; at top a hard pebbly bed 10 feet thick of round white quartz pebbles 1 inch in diameter; near base a hard 5-foot bed of coarse rounded quartz cobbles, 3 to 6 inches in diameter	35±
Thick granular purple, banded arkosic quartzite containing scattered pebbles	60±
Conglomerate of unassorted, quartz pebbles scattered through greenish sericitic, arkosic matrix	80±
Black slate	10±
	505±
Pre-Cambrian: Metabasalt and spotted green and blue volcanic slate.	

No section was measured in the Pigeon Hills because the formation is so broken by faulting that none is complete. The sequence of beds is best shown in the sharp ravine on the south side of the mountain, 2 miles north of New Baltimore, where the water supply for Hanover is obtained. The following sequence of beds with approximate thicknesses represents the Chickies quartzite in the Pigeon Hills:

Composite section of Chickies quartzite and Hellam member with estimated thicknesses in the Pigeon Hills

	Feet
Chickies quartzite:	
White vitreous quartzite, *Scolithus*-bearing	200±
Hellam conglomerate member:	
Massive-bedded conglomerate; some beds 20 feet thick makes high ridges and peaks	300±
Thin-bedded crumbly conglomerate	
Coarse conglomerate containing dark slate fragments	
Dark slate	20±
	520±
Pre-Cambrian rocks:	
Spotted volcanic slate.	
Amygdaloidal metabasalt.	

AGE AND CORRELATION

The Chickies quartzite north of Hanover-York Valley unconformably overlies metabasalt and aporhyolite of pre-Cambrian age and contains pebbles of blue and white quartz and slate derived from those rocks. The finer arkosic layers were derived in part from disintegrated "greenstone" and aporhyolite. *Scolithus* tubes are the only fossils in the Chickies quartzite, but the formation is conformably overlain by rocks that contain Lower Cambrian fossils and is therefore classed as Lower Cambrian. The Hellam conglomerate, the basal member of the formation, was named from the Hellam Hills in the Middletown quadrangle, where it is best developed.

CHICKIES SLATE SOUTH OF THE HANOVER-YORK VALLEY

DISTRIBUTION

South of the Hanover-York Valley equivalent rocks are so different from the typical Chickies quartzite north of the valley that they are described under the heading Chickies slate. Because it overlies the Hellam conglomerate member and underlies the Harpers phyllite, the slate is identified as the equivalent of the massive Chickies quartzite north of the valley. The Chickies slate occurs in three anticlines south of the valley, but the basal Hellam conglomerate member is exposed only in the northeastern anticline. In these anticlinal areas Chickies slate is surrounded by Harpers phyllite, and the formations together form a belt about 3 miles wide in the Stoner overthrust block southeast of the Hanover-York Valley.

The Chickies slate is exposed along the axis of the Mount Pisgah anticline and makes a series of prominent hills which are about a mile wide and extend from the northeastern edge of the district southwestward to York New Salem. Along the same anticlinal axis, northeast of Berkheimer School, is a small exposure of the slate. Chickies slate crops out in the Holtz anticline, 2½ miles southeast of the Mount Pisgah anticline, and extends from a point 2 miles east of Holtz southwestward to the East Branch of Codorus Creek southwest of Spry. This fold is double, as indicated by two parallel bands of quartzite exposed on the axes. In the Kraft Mill anticline, which lies southwest of the Holtz anticline but not along the same axis, Chickies slate extends from East Branch of Codorus Creek southwestward for 12 miles across the West Branch of Codorus Creek at Kraft Mill.

CHARACTER OF ROCKS IN THE MOUNT PISGAH ANTICLINE

In the Mount Pisgah anticline the Chickies is composed of black slate interbedded with thin quartzite. The best exposures are in the gorges of Kreutz and Mill Creeks, where the streams cut directly across the anticline, and on the East Branch of Codorus Creek northeast of York New Salem, where quartzite forms rocky cliffs.

The general slaty character of the formation is best shown in a quarry in the bluff on the east bank of the Susquehanna River south of Columbia. The rock exposed is chiefly black shiny slate with numerous thin platy layers of gray to rust-stained quartzite and layers of thicker quartzites in 2- to 3-inch beds containing black slate partings. The beds are folded tightly, and the folds are overturned to the north so that all the beds dip southward about 80°. The sequence of beds is uncertain, but a thicker-bedded quartzite is believed to mark the center of an anticline, with a zone or zones of thin-bedded quartzites in slate on the flanks. Sericitic quartzose beds with black slate layers are shown in plate 2, *C*.

The quartzite beds have been separately mapped only where they make conspicuous outcrops or debris-covered ridges. A thick quartzite above the Hellam conglomerate has been mapped on the north flank of the anticline from Kreutz Creek gorge to the river. Quartzite occurs also along the Stoner overthrust at several localities, such as Leiphart Mill, on the road southwest of

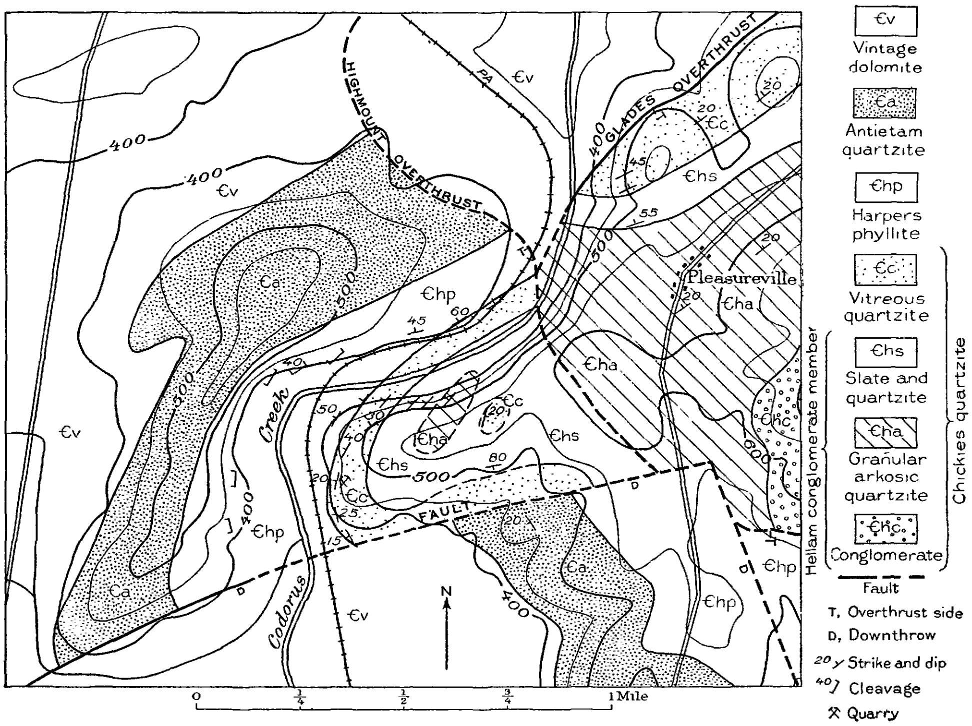


FIGURE 4.—Geologic map of gorge of Codorus Creek north of York, showing detailed areal distribution and interpreted structure of the quartzose Cambrian rocks at the plunging end of the Mount Zion anticline. Four stratigraphic divisions of the Chickies quartzite are mapped.

Stoner Station, and places to the east in the Middletown quadrangle. Quartzite, repeated by folding, is well exposed at a point north of Benroy, at the Paper Mill on Mill Creek, on the hills southeast of York, and in the gorges of East Branch and West Branch of Codorus Creek.

Several zones of quartizite beds have been observed in the slate but, because of poor exposures and repetition by folding, they cannot be traced far on the surface. In the northern part of the Mount Pisgah anticline the lower beds of the Chickies slate are exposed in the stream gorge south of Violet Hill. The structure there is interpreted as an anticline. (See fig. 5.)

The following section shows the character and sequence of the beds:

Partial section of Chickies slate south of Violet Hill

	Feet
Black slate, banded with lighter-colored sandy beds.	
Thin-bedded green quartzite (2-foot beds) in black banded slate	20±
Black slate containing some thin, platy quartzite Black slate banded with yellow earthy, sandy beds and green phyllite	50±
Thick-bedded greenish quartzite	30±
	100±

The exposure of quartzite and phyllite on the east side of Mill Creek south of Plank Road, which is interpreted as a syncline (fig. 6), shows the following sequence:

Partial section of Chickies slate on Mill Creek

	Feet
Harpers phyllite: Green phyllite.	
Chickies slate:	
Black slate	10±
Thin-bedded quartzite	15±
Black shale and thin green phyllite, and a 5-foot bed of white coarse, granular quartzite	65±
Thin-bedded rusty weathering granular quartzite with black slate partings and thin slate beds	20±
Black banded slate	50±
Hard thick-bedded coarse vitreous quartzite containing blue quartz grains (exposed in anticlines)	20±
	180±

The thick quartzite at the base of this section is believed to be the equivalent of the quartzite exposed in the bluff at the junction of the West and East branches of Codorus Creek, which there is estimated to be about 60 feet thick.

The exposures east of the York and Windsor Electric Railway, 2 miles south of York, also show anticlinal structure (fig. 5). Quartzite in a closely folded anticline is exposed east of the highway (U. S. 111) just south of the outcrop shown in figure 5. Northeast of York New Salem quartzite occurs in a compound fold. The quartzite in the northern anticline is undercut by Codorus Creek and forms the top of a cliff 200 feet high that faces north and is visible for miles. The southern anticline is cut through by Codorus Creek, 1 mile north of Brillhart, which has left a remnant of the quartzite at the axis of the anticline preserved as a rock pinnacle which rises 20 feet out of the stream flood plain. (See pl. 2 *D*.) In the eastern end of this fold the quartzite is exposed east of the road above Codorus Creek, 1½ miles southwest of the Violet Hill reservoir. In the cliffs below the York Country Club the quartzites are closely folded and an overturned anticline is exposed (fig. 7). Close folding of quartzite in the Chickies also is exposed south of Lehman, where the cleavage dips 60° SE.

A complete section of the formation can only be approximated because of the close folding, faulting, and poor exposures. The following composite section is based on scattered, partial sections and is a revision of the section previously published.[11]

Generalized composite section of Chickies slate in Mount Pisgah anticline

	Feet
Harpers phyllite: Green muscovite-quartz schist.	
Chickies quartzite:	
Thin-bedded quartzite and black slate	25±
Black slate and thin, platy green phyllite inclosing a 5-foot bed of hard white coarse, granular quartzite	65±
Thin-bedded greenish quartzite (2-foot beds) with black slate partings and interbedded black slate	20±
Black slate; some beds banded with yellow earthy-weathering, siliceous layers and green phyllite, and a few thin, platy quartzite beds	50±
Thick-bedded quartzite; some beds 12 feet thick; thinner-bedded quartzite at top and bottom	60±
Black slate with a few thin quartzite beds	100±
Hellam conglomerate member: Thick beds of conglomerate, containing pebbles 1½ inch in diameter; interbedded sericitic quartzite and thin black slate	30±
	350±

Based not exposed.

The gray muscovite quartzite with dark slate bands, from the upper part of the Chickies slate in the Pisgah anticline, show in thin section that the constituents are quartz, muscovite, and chlorite, with some zircon and tourmaline. The clastic quartz grains are somewhat granulated. Chlorite and muscovite fibers lie parallel to the cleavage and at an angle to the banded quartzose layers which indicate the bedding. The blue-gray fine-grained slate layers show only slaty cleavage and are composed of chlorite, muscovite, quartz, and fine albite grains. The slate contains also muscovite porphyroblasts which are not oriented with the cleavage.

In thin sections the phyllite layers of the Chickies slate show alternate micaceous and quartzitic bands. The platy minerals—muscovite and chlorite—are parallel to the cleavage. The rock contains also quartz and albite. Muscovite and chlorite porphyroblasts con-

[11] Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pa.: U. S. Geol. Survey Bull. 840, p. 18, 1933.

tain zircon inclusions with pleochroic haloes. The phyllites are the result of low-rank progressive metamorphism.

HELLAM CONGLOMERATE MEMBER

The Hellam conglomerate member of the Chickies slate is exposed only northeast of the Kreutz Creek gorge, in the center of the Mount Pisgah anticline, where it forms a series of ledges along the narrow ridge which rises to an altitude of 840 feet at Mount Pisgah. The best exposure of the conglomerate is just west of Yorkana on the east side of Kreutz Creek, where about thirty feet of beds are exposed. It crops out on the ridges to the northeast in two parallel belts which probably represent the crests of two folds. Each belt has two ledges of conglomerate, 20 to 40 feet wide, apparently marking the two limbs of a fold. The best exposure is near Brenneman School. The pebbles of the conglomerate are elongated parallel to the cleavage, which dips steeply to the southeast and has obliterated the bedding in large part. Southwest of Kreutz Creek the anticline plunges and the conglomerate member passes under the slate and does not reappear at the surface to the west.

The rock of the Hellam member is a cream to green schistose quartz conglomerate containing blue and milky quartz grains and pebbles as much as half an inch long and jaspery hematite which colors the rock pink to red on weathering. Cleavage planes in the conglomerate are coated with green muscovite. The conglomerate layers are interbedded with sericitic quartzite and thin black slate.

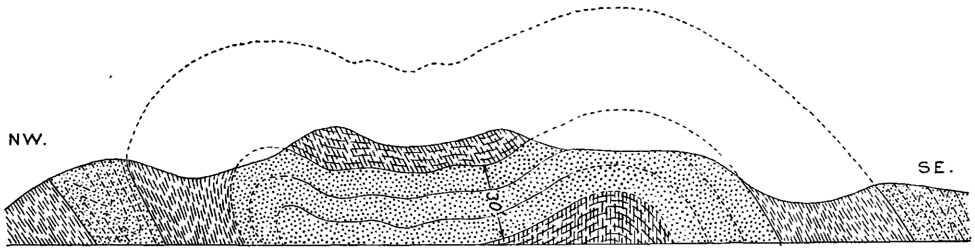


FIGURE 5.—Sketch of section, showing interpreted structure of quartzite beds in the Chickies slate along the York & Windsor Electric Railroad, south of Violet Hill, 2 miles south of York.

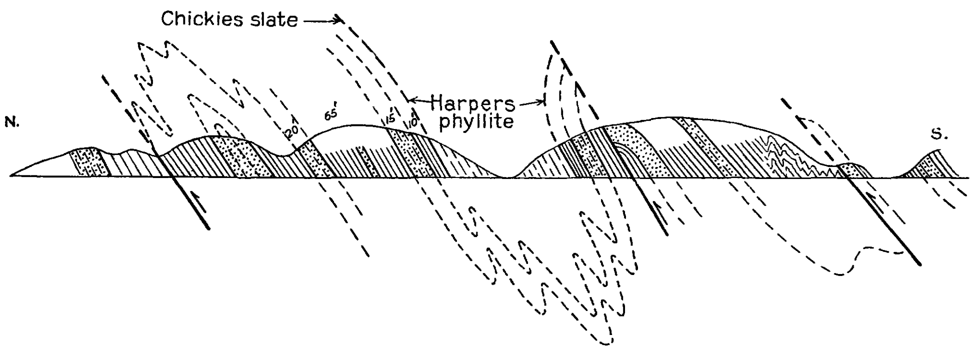


FIGURE 6.—Sketch of section of Chickies slate and interbedded quartzite on east side of Mill Creek south of Plank Road, showing interpreted structure.

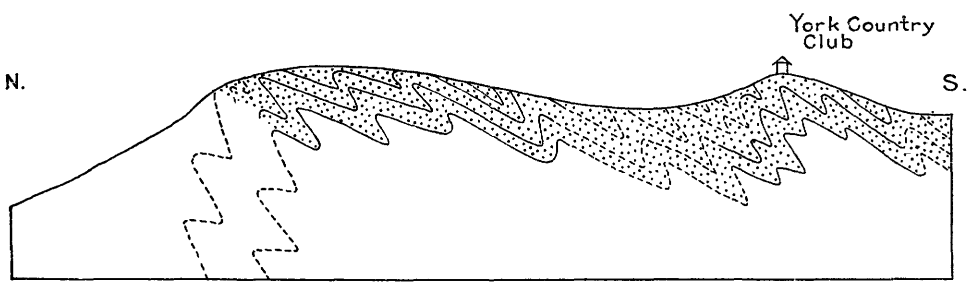


FIGURE 7.—Sketch of section showing anticlinal structure of quartzite beds in Chickies slate east of Codorus Creek near York Country Club.

CHARACTER OF ROCKS IN THE KRAFT MILL AND HOLTZ ANTICLINES

Only the upper part of the Chickies slate is exposed in the Kraft Mill anticline. The harder beds, which form ridges, are fine-to-medium-grained green quartzite with muscovite partings and thin interbedded black slate bands. Certain thick beds of quartzite are full of magnetite octahedrons, some facets of which are iridescent. In some places north of Strickhousers, the magnetite is so abundant that it has been prospected for iron. The rocks are closely folded, and the folds are cut by a prominent transverse cleavage. The beds are repeated by folding, but the depth of the exposures is not sufficient to give a complete sequence of beds. The general sequence seems to be:

Sequence of beds in Kraft Mill anticline

Harpers phylite: Gray phylite and quartzose schist with thin beds of quartzite containing magnetite.
Chickies slate:
- Black slate and phyllite
- Thick green ferruginous granular quartzite containing glassy quartz grains and abundant magnetite crystals.
- Black slate and thin, slabby dark quartzite containing coarse quartz grains.

The Chickies slate in the Holtz anticline is similar to that in the Kraft Mill anticline. Similar magnetitic green quartzite beds form a ridge from a point northeast of Holtz southwestward to East Branch of Codorus Creek. Large blocks of the quartzite are strewn over the surface of the ridge. The only outcrops are found in the valley of Mill Creek.

HARPERS PHYLLITE

NAME AND DISTRIBUTION

The Chickies quartzite is overlain by an argillaceous rock called the Harpers phyllite. The name Harpers shale was applied to argillaceous rocks at Harpers Ferry, W. Va. It there overlies the Weverton quartzite, which is in part equivalent to the Chickies quartzite in the Hanover-York district, and underlies the Antietam quartzite. The Harpers shale, therefore, occupies the same stratigraphic position in the section at the type locality as does the Harpers phyllite in the Hanover-York district where the argillaceous beds have been metamorphosed to a phyllite. Although the exposures of the formation in this district are not continuous with those at Harpers Ferry, the two areas are part of the same uplift.

The Harpers phyllite crops out on the south slope of Mount Zion Hill, where it is overlain by the Antietam quartzite on the flank of the fold, and at the west end, where it overlies the Chickies quartzite on the plunging end of the fold. The phyllite overlies the Chickies quartzite along the southeast slope of the Pigeon Hills. Near John Mummert School at the northeastern plunging end of the High Rock anticline, the outcrop of the formation expands to half a mile in width. On the south side of the Gnatstown anticline the extent is irregular owing to faulting. The phyllite passes under the overlying Antietam quartzite, as is well shown on the plunging end of the fold at Roth Church. The phyllite is well exposed at the plunging end of the Gnatstown anticline and in the centers of the minor anticlines farther south. It also forms the core of the Pottery Hill anticline southwest of West York.

South of the Hanover-York Valley, the Harpers phyllite and associated formations crop out in a belt about 4 miles wide that extends from the northeast edge of the district southwestward to the Maryland line, beyond the limits of the Hanover quadrangle. In this belt Harpers phyllite predominates, but there are anticlinal areas of the Chickies slate, already described, as well as infolds of the overlying Antietam quartzite, Vintage dolomite, and Conestoga limestone, chiefly in the East Prospect, Jefferson, and Stormy Hill School synclines. Southwest of York New Salem the Harpers phyllite was carried northwestward on the Stoner overthrust over the limestones of the Hanover-York Valley. Northeast of Hanover several small klippen of Harpers phyllite now lie on the limestone, having been detached by erosion from the Stoner overthrust block. The southern edge of this belt of Harpers phyllite is bounded by the Martic overthrust along which the rocks of the Glenarm series override the phyllite.

CHARACTER AND THICKNESS

The Harpers phyllite throughout the region is prevailingly an argillaceous rock. In the area north of the Hanover-York Valley, the dark-gray quartzose phyllite is somewhat streaked with light-gray quartzose bands, and in places, chiefly in its upper part, has thin quartzite beds. Bedding in the phyllite is nearly everywhere obscured by close folding and the development of cleavage. The parting planes are shiny with fine mica. The best fresh exposures are 2 miles north of York in the gorge of Codorus Creek and north of Glades to the river in the Middletown quadrangle. South of the Hanover-York Valley, thick beds of dense green ferruginous quartzite and magnetite-bearing gray quartzite in the phyllite have been mapped northeast of Benroy and north of the Jefferson syncline from East Branch of Codorus Creek to a point west of Sinsheim.

Because of close folding and the lack of observable bedding, the thickness of the Harpers phyllite can only be approximated. At John Mummert School on the southeast slope of the Pigeon Hills, where it lies in normal position between southeastward-dipping Chickies and Antietam quartzites, the thickness of the Harpers is estimated to be 1,000 feet. At the west end of Mount Zion Hill, where the Harpers is well exposed and clearly defined by outcrops of the enclosing quartzites in normal position, the thickness as determined from the width of outcrop and the dip of the adjacent quartzites is 800 feet. In the Hellam Hills in the Middletown quadrangle the average thickness was estimated to be 1,000 feet.

METAMORPHISM

Under the microscope, the Harpers phyllite of the Mount Zion and Pigeon Hills areas is seen to be composed of albite, muscovite, quartz, and fine blades of biotite. The mineral content and fineness of grain indicate that the metamorphism is a mild type of low metamorphic rank. South of the Hanover-York Valley, on the flanks of the Mount Pisgah, Kraft Mill, and Holtz anticlines, Harpers phyllite is more coarsely crystalline than in the Pigeon Hills and Hellam Hills. (See pl. 3, *A* and *B*.) The finely sparkling gray-green phyllite is composed of muscovite, chlorite, albite, and quartz, and is banded in places with thin quartzose layers. Muscovite and chlorite blades are parallel to the cleavage, but an incipient growth of chlorite and muscovite flakes is alined at an angle with the cleavage. The phyllite contains tourmaline and ragged porphyroblasts of ilmenite, some of which have chlorite rims. The rock is a paracrystalline phyllite produced by progressive metamorphism. The constituents of the rock and especially the porphyroblasts are not so coarse as those in the phyllites and schists farther southeast in the Martic overthrust block, but the composition is similar to that of beds in the Marburg schist lying adjacent to the southeast. In the argillaceous layers of the Harpers phyllite, the only visible structure is a closely spaced cleavage. In the quartzose layers, bedding is observable, especially in the arches of the folds where cleavage direction lies across the planes of stratification. Plate 3, *C*, shows the quartzose-layered variety of Harpers phyllite from the upper part of the formation. The thin section was cut from a specimen that came from the closely folded area near the edge of the Cabin Creek overthrust, 1½ miles west of Margaretta Furnace. A polished specimen of similar rock from near the same locality is shown in plate 18, *C*.

AGE AND CORRELATION

The Harpers phyllite nowhere contains fossils; however, the Antietam quartzite, which conformably overlies the formation, does contain Lower Cambrian fossils. Consequently, the Harpers phyllite is considered to be of Lower Cambrian age.

ANTIETAM QUARTZITE

NAME AND DISTRIBUTION

The Antietam quartzite is the uppermost of the Lower Cambrian quartzose formations. The name Antietam was first applied to similar quartzite which is exposed on Antietam Creek in South Mountain, Franklin County, Pa., and which occupies the same stratigraphic position as the Antietam quartzite of the Hanover-York district. Although the two areas are not directly continuous, they are parts of the same structural uplift.

The Antietam quartzite forms the outer rim of the anticlinal mountains and hills made of Cambrian quartzites. Along the southeast flank of Mount Zion Hill, the quartzite makes a narrow fluted band which curves around the southwestward-plunging end of the Mount Zion anticline. At that point the outcrop is sharply offset 1 mile by the west branch of the Highmount overthrust. Two miles northwest of York and west of the highway (U S 111), a small outlying hill of the quartzite is the extreme end of this anticline and was brought up between 2 diverging faults. In the Pigeon Hills the Antietam borders the northeastward-plunging end of the High Rock anticline around Roth Church and also borders in part the Harpers phyllite in the Gnatstown and Menges Mill anticlines to the south. It completely surrounds the Harpers phyllite of the Ambau anticline and spreads out into a fairly wide anticlinal area north and east of Mount Carmel School. The formation crops out discontinuously in a narrow strip along a strike fault east of Nashville. It borders the Harpers phyllite on Pottery Hill, a small but conspicuous anticlinal hill just south of Lincoln Highway (U S 30) and 1 mile west of West York.

South of the Hanover-York Valley, the Antietam is present in the Stormy Hill School syncline, which encloses the long narrow area of Vintage dolomite north of Porters Siding. South of the Kraft Mill anticline, the quartzite makes relatively wide belts in the Jefferson syncline where outcrops are well exposed on the north side of the syncline and in a subordinate anticline in the midst of the Conestoga limestone. In the southwesterly extension of the Jefferson syncline, in the area southeast of Wildasin Chapel, the Antietam surrounds the Conestoga limestone except where overridden on the southeast by rocks of the Martic overthrust. The largest synclinal area of Antietam south of the Hanover-York Valley extends from a point north of Spry to East Prospect, on the south flank of the Mount Pisgah anticline, and a narrower band continues northeastward to the Susquehanna River. The part east of Delroy lies on the north side of the East Prospect syncline, which forms a deep embayment of Conestoga limestone in places bordered by remnants of Vintage dolomite. An area of Antietam quartzite just south of Margaretta Furnace surrounds a syncline of limestone except on the south side, where it is cut off by the Martic overthrust.

CHARACTER AND THICKNESS

The Antietam quartzite is a gray quartzite weathering to rusty brown on bedding surfaces. The lower part of the formation is finer grained and has beds that are streaked with dark argillaceous matter, thus grading into the underlying Harpers phyllite. Hard blocky coarse-grained quartzite beds occur near the middle. At the top are granular ferruginous laminated quartzite beds which weather into porous rusty blocks owing to the solution of the calcareous matrix. Molds of fossils coated with yellow rust are revealed when the weathered rock is split on the bedding planes. The dark-red sandy soil derived from weathering of these beds contains residual iron ore.

The following section of the formation on the south slope of the Hellam Hills, 1 mile west of Wrightsville in the Middletown quadrangle is representative of the Antietam in the Mount Zion anticline:

Section of Antietam quartzite 1 mile west of Wrightsville

	Feet
Vintage dolomite:	
Impure sandy dolomite weathering to porous sandstone.	
Antietam quartzite:	
Slabby quartzite with rusty partings and fossil impressions	40
Coarse, granular porous-weathering fossiliferous quartzite	10
Quartzite with argillaceous streaks; weathering granular and white coated	150±
	200±
Harpers phyllite: Gray phyllite.	

South of Columbia, in the Lancaster quadrangle, the upper beds of the Antietam quartzite are well exposed in the river bluff:

Partial section of Antietam quartzite south of Columbia

	Feet
Vintage dolomite: Gray, knotty dolomite; basal beds siliceous, and contain a small amount of sphalerite, and merge downward into pyritiferous calcareous sandstone.	
Antietam quartzite:	
Fine-grained laminated gray quartzite and ferruginous quartzite composed of glassy quartz grains; contains pyrite and weathers rusty; top layer highly calcareous, pyrite abundant, weathers to rusty siliceous skeleton	10
Well-bedded fine-grained gray quartzite; highly ferruginous laminated beds contain fossils on bedding planes in lower part	30
Bluish schistose quartzite; no observable bedding; thickness not determinable.	

On the flanks of the anticlines of the Pigeon Hills, in the Hanover quadrangle, the Antietam quartzite is much thinner, and its exposures generally are poor. Its thickness here is estimated to be less than 100 feet. On the north side of the Jefferson syncline, along the state road between Seven Valleys and York New Salem, the Antietam is closely folded and has lenticular quartzose layers parallel to the vertical cleavage. An estimated thickness of 150 feet is probably much too great for this belt of the formation.

METAMORPHISM

The Antietam quartzite varies in coarseness of grain size and in rank of metamorphism in different parts of the area. In the Hellam and Pigeon Hills and Mount Pisgah areas, it is a fine- to medium-grained phyllitic quartzite, which, under the microscope, is shown to be composed of quartz, microcline, and albite, with muscovite forming the schistose partings. It contains small incipient porphyroblasts of biotite and, in places, of chlorite. The biotite contains inclusions of zircon with pleochroic haloes. Magnetite porphyroblasts are abundant. The lithologic character of the Antietam quartzite in the area north of the Hanover-York Valley is similar to that in the Strickler anticline. Plate 4, *A* represents a thin section of a specimen taken from the Strickler anticline 1 mile north of the edge of the York quadrangle and 2 miles north of Kline School. In the region south of the Mount Pisgah anticline and north of Margaretta Furnace, the biotite porphyroblasts are larger. They are plainly visible to the unaided eye, and, together with magnetite crystals, speckle the rock. In thin section (pl. 4, *B*) the biotite porphyroblasts are irregular in outline and intergrown with chlorite. A similar rock containing abundant porphyroblasts of biotite and magnetite (pl. 4, *C*) occurs between the Kraft Mill anticline and the Jefferson syncline. On the hill north of St. Pauls Church in the southwest extension of the Jefferson syncline, the Antietam quartzite is finer grained and its lithologic character resembles that of the rock in the Pigeon Hills area.

The present quartzite was produced by progressive metamorphism which varied in degree in different parts of the district. The area of maximum intensity lies in the East Prospect syncline, of the York quadrangle, as indicated by the coarse crystallinity of the Antietam and the large size of the contained biotite flakes. To the southwest and northwest of this syncline, metamorphic intensity wanes. The zone of maximum intensity of metamorphism of the Antietam quartzite in the East Prospect syncline is related probably to that in the belt around Mine Ridge,[12] farther east, where the Lower Cambrian Antietam quartzite, the basal part of the Vintage dolomite, the Conestoga limestone, and the Wissahickon formation contain coarse biotite. The variable degree of metamorphism of the Paleozoic rocks is discussed in the description of the metamorphism of the rocks of the Martic overthrust block.

AGE AND CORRELATION

The upper beds of the Antietam quartzite are locally fossiliferous. The fossils are internal and external molds and are generally too poorly preserved to be specifically determined. Fragments of olenellid trilobites and the small brachiopod, *Obolella minor*, are the most abundant and most diagnostic forms. Walcott[13] identified *Camarella minor*, *Obolella crassa* (?), *Hyolithes communis*, and *Olenellus* sp. from these beds in the vicinity of Emigsville. This list as revised by Resser,[14] is as follows: *Obolella minor*, *O. crassa* (?) (possibly identical with *O. minor*), *Hyolithes* sp., and *Olenellus* sp. All are Lower Cambrian forms. The writers collected some of the species listed above from a point 3 miles west of Wrightsville.

[12] Knopf, E. B., and Jonas, A. I., op. cit., (Bull. 799) pp. 129–141.

[13] Walcott, C. D., The Cambrian rocks of Pennsylvania: U. S. Geol. Surv. Bull. 134, p. 15, 1896.

[14] Resser, C. E., personal communication, 1938.

VINTAGE DOLOMITE

NAME AND DISTRIBUTION

The Vintage dolomite is the oldest carbonate formation of the Cambrian system in the Hanover York Valley. The formation was named[15] from its exposures along the Pennsylvania Railroad at Vintage station, Lancaster County, Pa. The dolomite grades downward through calcareous quartzose beds into the Antietam quartzite and, therefore, generally borders hills of Antietam quartzite throughout the area.

Vintage dolomite in a narrow band a quarter to an eighth of a mile wide, parallels the hills of Antietam quartzite on the north side of the York-Wrightsville Valley. This is the southwest end of a band that lies between the Antietam quartzite and Kinzers formation, which border the south side of the Hellam Hills anticlinorium in the Middletown quadrangle. The width of the formation expands to more than a mile at the westward-plunging end of the fold north of York. This band passes northward out of the York quadrangle and westward into the Hanover quadrangle before it is covered by the Triassic sedimentary rocks. A small area of the dolomite and the underlying Antietam quartzite is brought up in narrow fault blocks 1½ miles north of York.

On the south side of the York-Wrightsville Valley a narrow strip of Vintage dolomite between the Antietam quartzite and Kinzers formation extends from Leiphart Mill southwest to Plank Road. Vertical beds of knotty Vintage dolomite in a tight syncline in the Antietam quartzite are exposed in the railroad cut just south of Plank Road. At this point these beds are cut off on the south by the Stoner overthrust. Farther southwest the Vintage is covered by the Stoner overthrust. A narrow band of the dolomite follows the borders of the folded Antietam quartzite in the East Prospect valley in the northeast corner of the York quadrangle. Near East Prospect, the Vintage is overlapped by the Conestoga limestone and does not crop out at East Prospect nor westward for 2 miles. A small area of Vintage dolomite is exposed again at the border of the Conestoga limestone on Cabin Creek, 1 mile west of Margaretta Furnace, and another is exposed between the Antietam quartzite and the Conestoga limestone in the valley 1 mile south of Margaretta Furnace.

One of the largest areas of the formation is more than 1 mile wide and forms an arc around the Antietam quartzite at the eastward-plunging end of the Pigeon Hills anticline, east of La Bott. The Vintage dolomite borders the Antietam quartzite in several faulted anticlinal folds between Nashville and Mt. Carmel School and underlies the valley southward to the Stoner overthrust. It is exposed at two places in the Sprenkle School anticline within the broad outcrop of Kinzers formation northeast of Spring Grove. North of Hanover, the dolomite borders the Antietam quartzite on the south side of the Pigeon Hills and curves around the westward-plunging ends of two small anticlines of the quartzite at the edge of the Hanover quadrangle and in the adjacent Gettysburg quadrangle. A narrow strip of Vintage dolomite borders the Antietam quartzite in the syncline 1 mile northeast of Porters Station. A still smaller area is exposed beneath the Conestoga limestone in the Jefferson syncline north of Seven Valleys.

CHARACTER AND THICKNESS

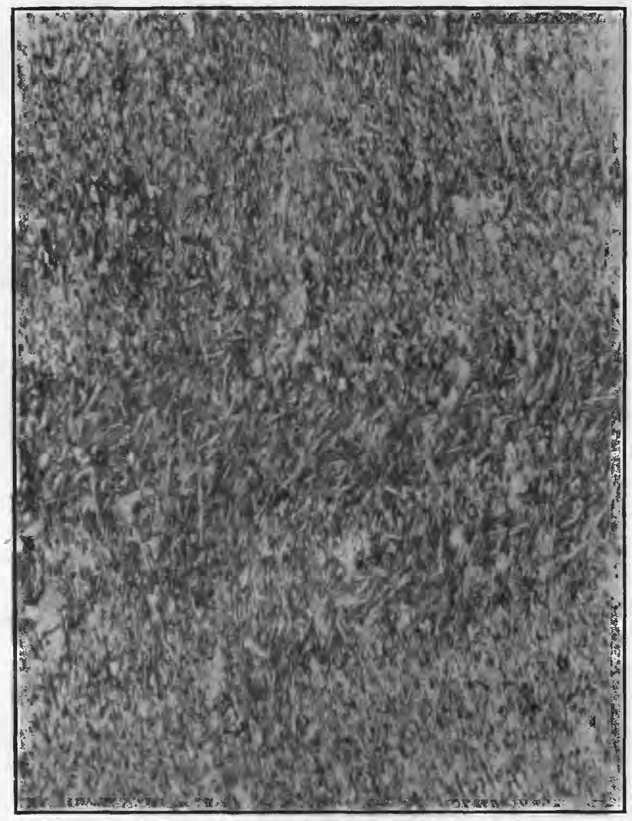
The Vintage dolomite may be divided into two parts. The lower part is chiefly a blue knotty, "mud lump" dolomite, and the upper part, a pure fine-grained limestone. At the base of the lower division is a white quartzoze marble that grades downward into the underlying Antietam quartzite. Although this basal bed is seen at few places, it is well exposed in a small ravine 1 mile south of Columbia, in the Lancaster quadrangle, on the east side of Susquehanna River. The blue knotty dolomite is well exposed in a quarry south of Wrightsville, on the south bank of Kreutz Creek, where it was quarried for concrete used in the construction of the bridge on the Lincoln Highway (U. S. 30) built across the river in 1930. The dolomite exposed there is about 100 feet thick, in part well bedded and in part massive with no visible bedding. Other outcrops of the lower knotty dolomite occur in several ravines at the foot of the hills on the south side of the York-Wrightsville Valley and in the valley of Codorus Creek just south of the point where the creek enters its rocky gorge, 2 miles north of York.

The higher beds of the formation are mostly pure fine-grained limestone, finely banded or mottled by dark wavy layers. These beds are well exposed in many small abandoned quarries in the vicinity of La Bott. These upper pure beds have not been observed in the eastern part of the area where probably they are very thin or absent.

In general the Vintage dolomite is poorly exposed because it is more soluble than the enclosing quartzites and shales and, therefore, forms lowlands, in part covered with quartzite debris between high hills of Antietam quartzite and lower hills of the Kinzers formation. The lower dolomite of the formation weathers to a characteristic granular maroon clay which covers the lower slopes of the Antietam quartzite hills.

Because of poor exposures, the thickness of the formation is difficult to determine. In the La Bott area, where the formation dips gently away from the plunging end of the Pigeon Hills anticline without duplication of beds by minor folding, the thickness, computed from the width of outcrop and the general dip, is 800 feet. In the narrow bands of the formation west of

[15] Stose, G. W., and Jonas, A. I., Lower Paleozoic section of southeastern Pennsylvania: Wash. Acad. Sci. Jour., vol. 12, no. 15, p. 362, 1922.

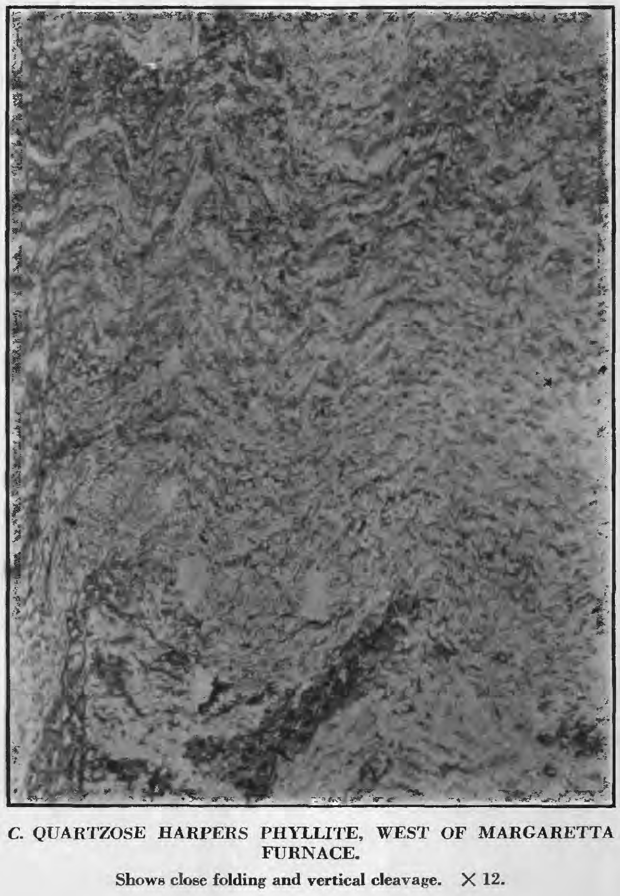


A. HARPERS PHYLLITE, 1 MILE WEST OF JACOBUS.

Foliation (dark bands) horizontal, cleavage vertical. Muscovite poryphyroblasts (white needles) intersect cleavage at an angle. × 27.

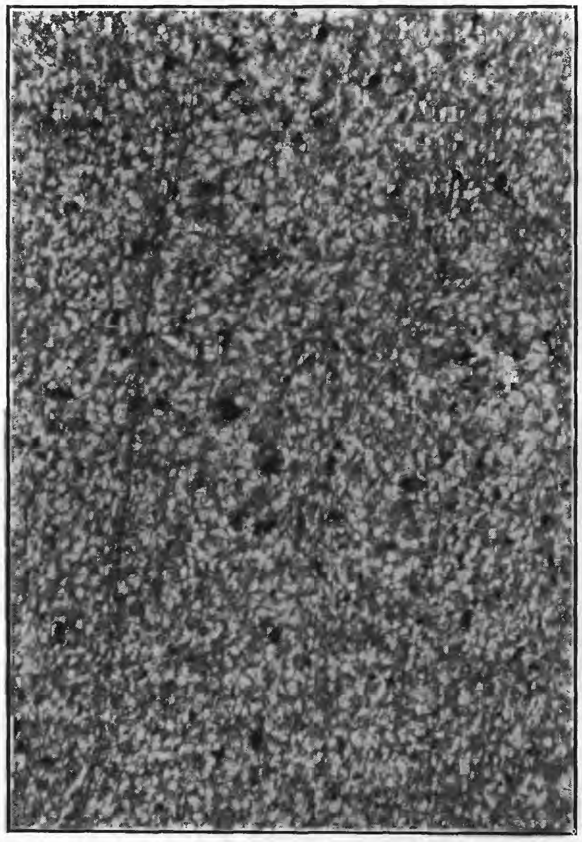
B. QUARTZOSE HARPERS PHYLLITE, SOUTH OF LEHMAN.

Shows slip cleavage crossing the banding. × 9.

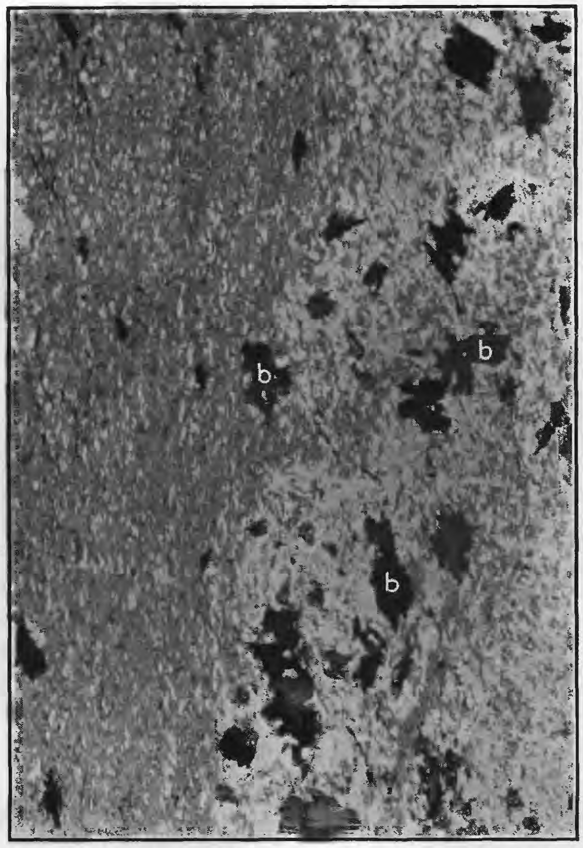


C. QUARTZOSE HARPERS PHYLLITE, WEST OF MARGARETTA FURNACE.

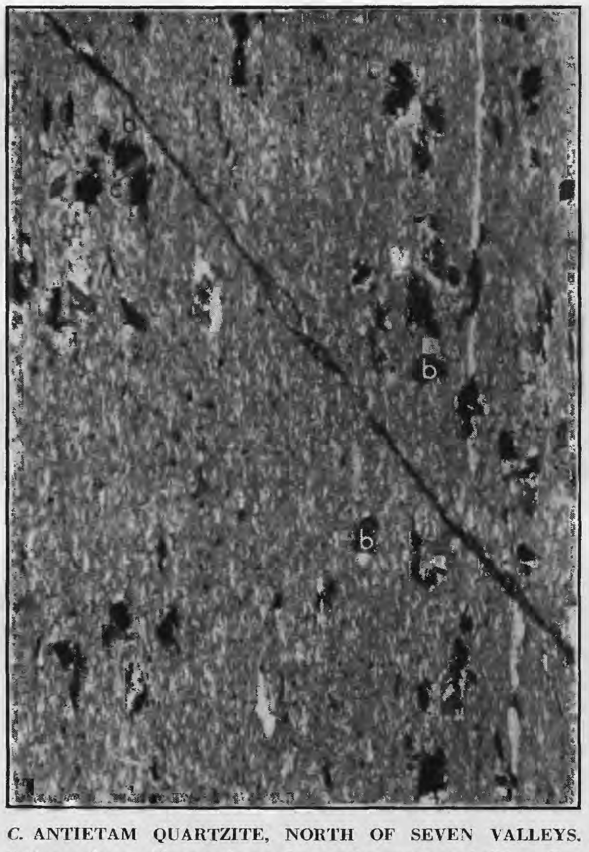
Shows close folding and vertical cleavage. × 12.



A. ANTIETAM QUARTZITE FROM STRICKLER ANTICLINE.
Constituents are quartz and albite (white), muscovite (gray), and biotite (black). × 15.



B. ANTIETAM QUARTZITE, EAST OF CANADOCHLY CHURCH.
Biotite porphyroblasts (b). × 15.



C. ANTIETAM QUARTZITE, NORTH OF SEVEN VALLEYS.
Schistose phase, with groundmass of muscovite, quartz, and albite. Porphyroblasts of biotite (b) banded in part with chlorite (c). × 15.

Nashville and southwestward, the thickness is apparently not more than 500 feet. On the south side of the York Valley, southeast of Stoneybrook and eastward into the Lancaster quadrangle southeast of Columbia, the Vintage dolomite is very thin, probably not more than 200 feet thick; and the upper purer limestone of the formation apparently is not present. The thinness of the Vintage and Kinzers formations, together with the absence of some of their members, along the southeast sides of the Wrightsville and Columbia Valleys, suggests that in this area the sea was shallow during Vintage and Kinzers time and that the shore was nearby to the south.

The most complete exposure of the Vintage dolomite in the region is in the vicinity of Emigsville, just north of York quadrangle. The following composite section was made from numerous disconnected outcrops and exposures in quarries. The estimated thicknesses in the concealed portions may be greatly in error, and the total thickness is believed to be not more than 1,000 feet.

Section of Vintage dolomite near Emigsville

	Feet
Vintage dolomite:	
Upper part:	
Top of formation concealed by Glade overthrust half a mile south of Emigsville.	
Concealed in small stream valley (some beds of white siliceous chalky marble weathering to buff tripoli near middle, and some light-gray jointed dolomite in upper part). Estimated thickness	320±
Pure fine-grained dark-blue and white mottled limestone containing some dolomitic bands and lumps (probably same as the *Salterella*-bearing beds near La Bott)	40±
Coarsely crystalline white and black brecciated marble and dark-blue glistening dolomite	180±
Light-blue limestone containing coarser dolomite blebs, and blue and white streaked limestone with dolomite mud-lump structure; weathers knotty and dirty-gray	80
	620±
Lower part:	
Impure blue and gray mottled sheared dolomite; weathers dirty-gray	40
Dark-gray sparkling knotty dolomite with lighter-gray coarsely crystalline blebs and stringers, and thin bands alternately dark and white; mud-pellet layer at top	15
Dark fine-grained dolomite, finely banded and showing finely conglomeratic character on weathering	20
Massive light-gray fine-grained dolomite	30
(The three units described above are exposed in a quarry in western part of Emigsville.)	
Light-gray dolomite containing coarser dolomite blebs	35
Blue and white laminated marble; fossiliferous blue limestone at top	90

	Feet
Vintage dolomite—Continued.	
Lower part—Continued.	
Concealed (fragments of slabby light-blue limestone with shaly partings). Estimated thickness	350±
Spotted dolomite; weathered surfaces pitted with flat holes (pebbles?) (quarry east of Emigsville)	25
Covered north of Emigsville. (The basal beds are not exposed here but elsewhere are white to pinkish, cream-colored laminated fine-grained marble becoming siliceous downward and merging into the Antietam)	200±
	805±
	1,425±
Antietam quartzite: Rusty quartzite in Pennsylvania Railroad cut north of Emigsville.	

The Vintage dolomite on the south side of the York-Columbia Valley is much thinner than near Emigsville, as is shown in the exposures on the east side of the Susquehanna 1 mile south of Columbia:

Section of Vintage dolomite 1 mile south of Columbia

	Feet
Kinzers formation: Blue calcareous slate and gray slate.	
Vintage dolomite:	
Blue knotty dolomite	10±
Concealed in valley, estimated	40±
Very massive dolomite	20
Knotty gray dolomite; thin-bedded character brought out by weathering; basal layer contains small amounts of sphalerite and galena and grades downward into pyritiferous calcareous quartzite	140±
	210±
Antietam quartzite: Calcareous granular quartzite.	

The top of the Vintage dolomite is well exposed in the Northern Central Railroad cut west of the quarry of the Universal Gypsum & Lime Co., formerly the Palmer Lime & Cement Co., in West York. These beds contain cystid plates and are of interest because fossils are very scarce in the formation.

Section of upper part of Vintage dolomite southwest of West York

	Feet
Kinzers formation: Shale.	
Vintage dolomite:	
Gray dolomite; weathers dirty-colored	10±
Mud-lump dolomite, and impure dark and light dolomite containing coarse crystalline specks	12
Impure dolomite; weathers to concentric banding	5
Crumbly dolomite; weathers dirty-colored	8
Light-blue limestone; weathered surfaces are white and blue mottled with dark impurities, and bedding surfaces are pitted and "worm eaten." Contains cystid plates which weather in relief	7
Blue fine-grained dolomite; weathered surface, dirty-buff	10
	52±

AGE AND CORRELATION

The few fossils known from the Vintage dolomite include fragments of trilobites, phyllopod shells, and cystid plates. *Salterella conica* was found in pure limestone beds in the upper part of the formation near La Bott and at two places 1 mile east of La Bott. Cystid plates of unidentified genera occur in the limestone interbedded with dolomite just above the Antietam quartzite in a cut of the Pennsylvania Railroad south of West York.

The fossils that have been identified from the formation in this and nearby areas are of Lower Cambrian age. The Vintage dolomite immediately underlies shale and limestone of the Kinzers formation which contains a large fauna of Lower Cambrian age.

KINZERS FORMATION

NAME AND DISTRIBUTION

The Kinzers formation was named from exposures at Kinzers Station on the Pennsylvania Railroad, Lancaster County, Pa., where its relation to the underlying Vintage dolomite is well shown. In the Hanover-York district the most characteristic features of the formation are the shale at the base and the impure calcareous and argillaceous sandstone at the top. These members generally make low ridges and in places form prominent hills. A narrow valley formed in the middle calcareous member generally lies between parallel hills of these harder members. The shale at the base was mapped separately throughout the area. In the vicinity of Penn Grove and north of East Prospect, this shale is the only part of the formation present. The sandy and earthy beds at the top of the formation have been mapped not only where they make conspicuous ridges but also in places where the ridges were not prominent, because such mapping was essential to solve the structural relations. South of the Gnatstown overthrust the upper sandy beds are very thin and were not mapped separately.

The Kinzers formation, with its two lines of ridges and narrow intervening valley, extends along the north side of the York-Wrightsville Valley from York northeastward and crosses the Middletown quadrangle to Susquehanna River. The shale and sandstone ridges are very low, but the sandstone ridge is the more conspicuous. The town of Hellam, just north of the York quadrangle, is located on the sandstone ridge. The members of the formation are repeated by faulting north of Campbell.

North and northwest of York the basal shale makes prominent ridges crossed by the highway (U. S. 111): but, owing to faulting, the ridges are not continuous. The shale forms several hills in the York Valley, west of York, along the border of the overlapping Triassic sediments. Prominent isolated hills of the upper sandstone member are the sites of Greenmount Cemetery and of Farquhar Park northwest of York. (See figs. 9 and 10.) On the south side of York-Wrightsville Valley, from Leiphart Mill to Plank road, the lower shale member is a narrow band, the north side of which is overlapped by the Conestoga limestone.

South of West York on both sides of West Branch of Codorus Creek, the Kinzers formation occurs in several folds, which are broken by faults. The Universal Gypsum and Lime Co., formerly Palmer Lime and Cement Co., has a quarry in the limestone member south of a hill of basal shale. The Eli Zinn quarry, just south of York, on the north side of Codorus Creek, is also in this limestone, and the upper sandstone member forms the top of the quarry and the hill to the north on which Highland Park is located. (See fig. 16.)

The threefold divisions of the Kinzers formation is displayed best near Thomasville, where the dips are low on the plunging end of the High Rock anticline of the Pigeon Hills, and consequently the members form wide bands. The upper sandstone makes the hill southeast of Thomasville, and the basal shale makes the crescent-shaped ridge that curves around the plunging end of the High Rock anticline southwest of Thomasville. The quarries of the Thomasville Stone and Lime Co. and of J. E. Baker & Co., at Thomasville, are in the pure limestones of the middle member.

An irregular belt of hills of the Kinzers formation enclosing a narrow valley in Vintage dolomite extends from a point south of West York southwestward to Spring Grove. The anticlinal structure of this belt could be worked out only by mapping separately the shale at the base of the Kinzers formation. The two overlying members are not separated because the upper sandstone beds here are thin. The Kinzers formation is preserved on the flanks of several minor anticlines, such as those north of Nashville and at Menges Mills, and north of Iron Ridge it nearly surrounds the anticlinal hill of Antietam quartzite. In these areas also the shale at the base was mapped separately. In the limestone cove at Penn Grove, in the areas around York Road, Smith Station, and a point 1 mile north of Smith Station, as well as in the eastern part of the district northeast of East Prospect, only shale is present, as the Conestoga limestone apparently overlaps the higher beds.

CHARACTER AND THICKNESS

The Kinzers formation is composed of three distinct members. The lower one is a black to gray argillaceous shale. In the vicinity of the Getz quarry in the Lancaster quadrangle light-gray to light-blue argillite with hackly fracture contains fine specimens of trilobites. In the Hanover-York district the shale is closely folded and cleavage is so well developed that the bedding is obliterated and no fossils have been found.

At many localities the shale contains pyrite cubes or rusty pits where the cubes have been removed by weathering. Cleavage planes usually are stained by iron oxide. Southwest of Spring Grove the shale beds of the lower member have been altered into a black, shiny, finely micaceous phyllite.

The middle member is predominantly limestone of variable composition. Some of it is a pure high-calcium rock and is extensively quarried by two companies near Thomasville, one in West York, and two west of the shale hill that lies 1½ miles west of West York. Several of the limestone beds have a spotted or mottled appearance, caused by the enclosure of rounded or lenticular masses of white crystalline limestone in argillaceous or earthy layers. These spotted beds are called "leopard rock." On weathering, the impure layers stand in relief, and a reticulate earthy network may result. (See pl. 5, *A*.) The "leopard rock" occurs also in the section at the type locality. The peculiar structure is apparently of organic origin and related to the archaeocyathid reefs found in some of the purer limestones of the formation at the Eli Zinn quarry on the east face of Greenmount Cemetery Hill and at the S. Forry Laucks quarry. Rocks of the same age near Austinville, Va.,[16] contain similar reefs.

Partial recrystallization in some of the pure beds has produced a conglomeratic appearance. These layers contain rounded residual masses of finely crystalline dark limestone enclosed in light-gray to white coarser-grained recrystallized marble. Other beds are true conglomerates composed of coarse marble fragments. Pure limestone in some beds has been altered in part to coarse-grained dolomite, the replacement starting along fractures and thence spreading irregularly into the mass. (See fig. 12.)

The upper member of the formation is usually an earthy or fine-grained quartzose limestone containing dark argillaceous layers. The beds weather to buff dense, tough tripoli, porous fine-grained sandstone, or dark dry earthy banded shale. Fossils have been found in the weathered rock at most of its outcrops in the Hanover-York district. These sandy beds are most conspicuously exposed on a prominent hill southeast of Thomasville.

On the north side of the York-Wrightsville Valley also, the upper sandy member makes a distinct low ridge which extends into the adjoining Middletown and Lancaster quadrangles. When the reports[17] on those quadrangles were published, this sandy limestone was thought to be the basal part of the overlapping Conestoga limestone and was so shown on the maps in the reports. Fossils collected recently from the sandy beds in the York and Hanover quadrangles as well as in the area to the northeast prove the member belongs in the Kinzers.[18] A revised map of the southern part of the Middletown quadrangle is shown in figure 24 and on the geologic map of York County.[19] The character of the Kinzers formation is so varied that a large number of detailed sections from quarries and other good exposures are presented. Most quarries are in the thick-bedded pure limestone of the middle member; and at many of them, the sandy and earthy limestones of the upper division cap the quarry faces. The boundary between the upper and middle members is not everywhere well defined because of the variable occurrence of the sandy and earthy beds.

In the Lancaster-New Holland area the Kinzers formation is 150 to 200 feet thick. The character of the beds is shown in the following composite section derived from exposures in the New Holland quadrangle at Kinzers, the type locality 13 miles southeast of Lancaster, and in the Lancaster quadrangle at Rhorerstown, 3 miles northwest of Lancaster:

Composite section of Kinzers formation in Lancaster and New Holland quadrangles

	Feet
Ledger dolomite: Massive granular gray dolomite.	
Kinzers formation:	
Upper member:	
Impure white marble with siliceous partings; weathers to tough tripoli	20±
Sandy dolomite; weathers to tough hard porous fine-grained sandstone	5
Concealed	20
	45±
Middle member:	
Dark-blue limestone with wavy argillaceous partings and thin layers of gray dolomite	30±
Dark earthy limestone spotted with white ("leopard rock")	10
Tough sandy fossiliferous blue dolomite; weathers buff and somewhat ribbed	20
Dense blue impure limestone with nodules of pure limestone ("leopard rock")	6
Blue limestone with fine wavy argillaceous laminations	10
	76±
Lower member:	
Dark fissile shale	35–70
Earthy fossiliferous blue dolomite; weathers to buff or orange-colored tripoli or porous sandstone	7
	42–77
	163–198±
Vintage dolomite: Massive light-gray dolomite.	

[16] Stose, G. W., and Jonas, A. I., A southeastern facies of Lower Cambrian dolomite in Wythe and Carroll Counties, Va. Va. Geol. Survey, Bull. 51–A, pp. 10–22, 1938.

[17] Stose, G. W., and Jonas, A. I., The geology and mineral resources of the Middletown quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 840, p. 35, 1933. Jonas, A. I., and Stose, G. W., Lancaster quadrangle: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas No. 168, p. 47, 1930.

[18] Jonas, A. I., and Stose, G. W., Age reclassification of the Frederick Valley (Maryland) limestones: Geol. Soc. Am. Bull., vol. 47, p. 1671, 1936.

[19] Stose, G. W., and Jonas, A. I., Geology and mineral resources of York County, Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. C–57, pl. 1, 1939.

In the reports on the New Holland [20] and Lancaster [21] quadrangles the writers recognized the threefold division of the formation but did not separate it into the three members.

Another nearly complete section is exposed along the river bank just north of Wrightsville, where the pure marble of the middle member has been extensively quarried. In the report on the Middletown quadrangle,[22] these pure beds were included in the Ledger dolomite; but now the marble is known to be part of the Kinzers formation. (See sketch map and section, fig. 8.)

Revised composite section of Kinzers formation and overlying limestones north of Wrightsville

	Feet
Conestoga limestone (south quarry):	
Argillaceous limestone conglomerate, banded argillaceous blue limestone, and thick granular crystalline limestone	
Black argillaceous limestone and thin shale; ripple marked	200±
Marble; 2-foot bed	
Conglomerate composed of dark slabby limestone fragments and 6-inch angular masses of white marble in black slaty matrix	
Wall rock, concealed (some slaty limestone with shale partings. Large spring near base)	220±
	420±
Ledger dolomite (middle quarry):	
White to blue mottled coarsely crystalline dolomite	105±
(West of road on upland in quarry above river, 50 feet of dark argillaceous to earthy, closely folded limestone makes a horse.)	
Kinzers formation:	
Upper member (wall rock):	
Dark slaty, argillaceous limestone and hackly dark dolomite	10±
Thin fissile to platy black earthy shale	5
Earthy-banded blocky sandy limestone; weathers to hard sandstone and to porous sandstone pitted by solution and removal of limestone pebbles	20±
Concealed	35±
Black fissile shale and slaty limestone	40±
Slaty blue limestone and knotty blue dolomite; rough bedding surfaces; carbonaceous partings	25
	135±
Middle member (north quarry):	
Dark and light spotted crystalline marble ("leopard rock")	10
Massive-bedded white coarsely crystalline marble	30±

[20] Jonas, A. I., and Stose, G. W., New Holland quadrangle: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas No. 178, pp. 11–12, 1926.

[21] Jonas, A. I., and Stose, G. W., Lancaster quadrangle: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas No. 168, pp. 26–29, 1930.

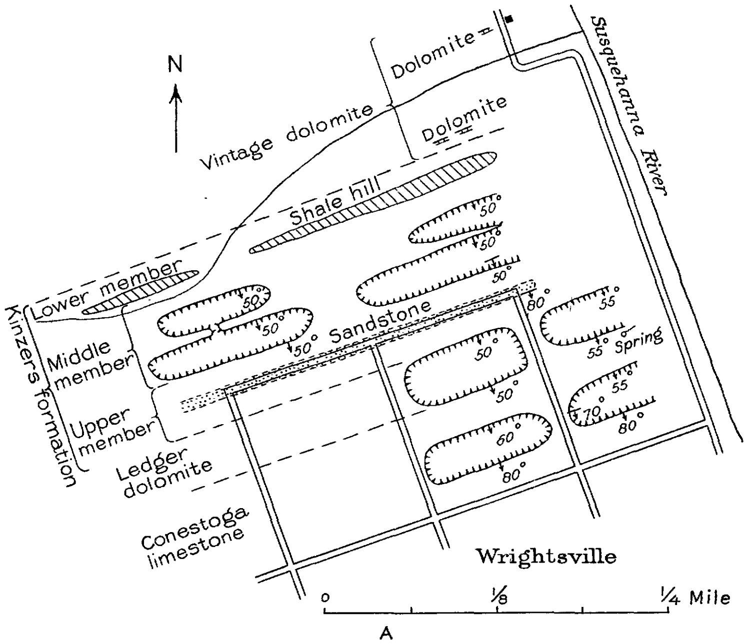
[22] Stose, G. W., and Jonas, A. I., The geology and mineral resources of the Middletown quadrangle: U. S. Geol. Survey Bull. 840, pp. 28 and 34, 1933.

	Feet
Kinzers formation—Continued.	
Middle member (north quarry)—Continued.	
Light-gray dolomite (horse in quarry)	5
Very massive-bedded mottled white coarsely crystalline marble; some limestone conglomerate in middle; thinner bedded at base	50±
Blue limestone	10
Concealed	80±
	185±
Lower member:	
Concealed	70±
Dark shale (forms hill)	30
	100±
Total thickness of Kinzers formation	420±
Vintage dolomite: Dark knotty dolomite.	

The upper part of the formation is well exposed along the railroad track south of the quarry of the Thomasville Stone and Lime Co. Including the pure beds in the quarry and estimating the thickness of the lower shale, which is poorly exposed in the ridge to the west, the thickness of the formation here is about 400 feet.

Section of Kinzers formation in vicinity of the Thomasville Stone and Lime Co. quarry

	Feet
Upper member (in railroad cut south of quarry):	
Hard dense light-blue limestone; weathers to tough light-buff banded sandstone, stained red in places (sandstone fragments cover top of hill south of Thomasville)	20±
Concealed	30±
Thin-bedded impure blue limestone with fine wavy siliceous banding which weathers to network of buff dense tripoli, and thin dark fossiliferous crystalline limestone containing cystid plates and trilobite and shell fragments (pl. 5, *A*)	50±
Impure shaly limestone (poorly exposed)	30±
Banded, very earthy blue limestone; weathers to fine dense siliceous, earthy buff network	20±
Blue to white impure marble; weathers to buff banded tripoli with crystalline cystid plates on surface	10
Earthy blue limestone interbedded with purer limestone at base; weathers to thick-bedded dense earthy sandstone	20
Blue limestone conglomerate	5
Earthy dolomite; weathers to tripoli	3
	188±
Middle member:	
Concealed (between quarry and railroad cut south of quarry). Estimated thickness	40±
Dark even-grained limestone with wavy banding; bands that weather to buff color stand in relief and contrast with chalky white coating on the adjacent bands; basal bed is conglomerate of pebbles of fine-grained marble in dolomite matrix (top beds in quarry face)	20
Minor unconformity.	



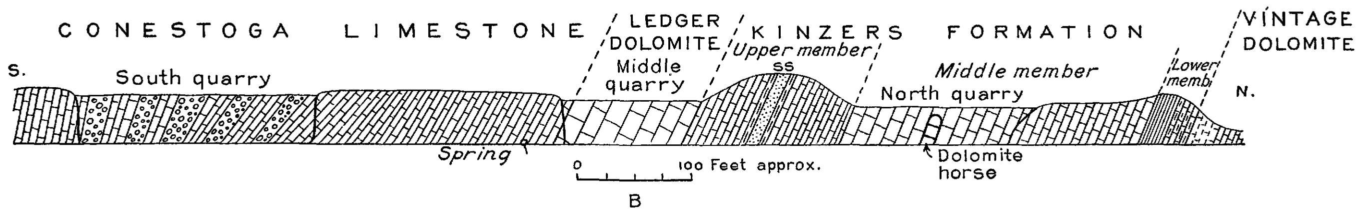


Figure 8.—Geologic sketch map and section of the limestones north of Wrightsville: A, Map of northern part of Wrightsville, showing the location of old limestone quarries and revised geologic mapping; B, Section along river bluff north of Wrightsville, showing revised correlation of beds exposed.

	Feet
Middle member—Continued.	
White to pink even-grained granular crystalline limestone with occasional black blotches; some beds resemble conglomerate (quarry rock, reported to average 98 percent $CaCO_3$ and some beds 99.69 percent)	60
	120±
Lower member:	
Concealed. Estimated thickness	50±
Black shale (in hill west of railroad). Estimated thickness	50±
	100±
	408±

Just north of the York quadrangle another good section is exposed in the Pennsylvania Railroad cut half a mile south of Emigsville, and in an adjacent quarry. The beds here dip southward 15° and the sequence is inverted, the limestone of the upper part of the formation dipping beneath the shale. The sandy beds at the top of the formation are faulted out.

Partial section of Kinzers formation half a mile south of Emigsville

	Feet
Upper part of formation not exposed.	
Middle member (exposed chiefly in quarry):	
Light-blue hard limestone; much sheared	80± (bracketed)
Knotty blue limestone with magnesian mottling	
Banded light-blue limestone containing cystid plates and other fossils	
Dark massive dolomite	
Laminated mottled limestone; conglomeratic crystalline beds contain cystid plates and other fossils (Top of quarry face)	
Concealed	30±
Tough dense sandy dolomite; weathers to soft buff porous tripoli or fine standstone	20±
	130±
Lower member (exposed in railroad cut):	
Gray platy shale	125
Concealed (shale and sandstone fragments)	25±
White saccharoidal dolomite containing many glassy quartz grains and weathering to blocky earthy buff sandstone, and hard bluish granular quartzite slabs	10±
	160±

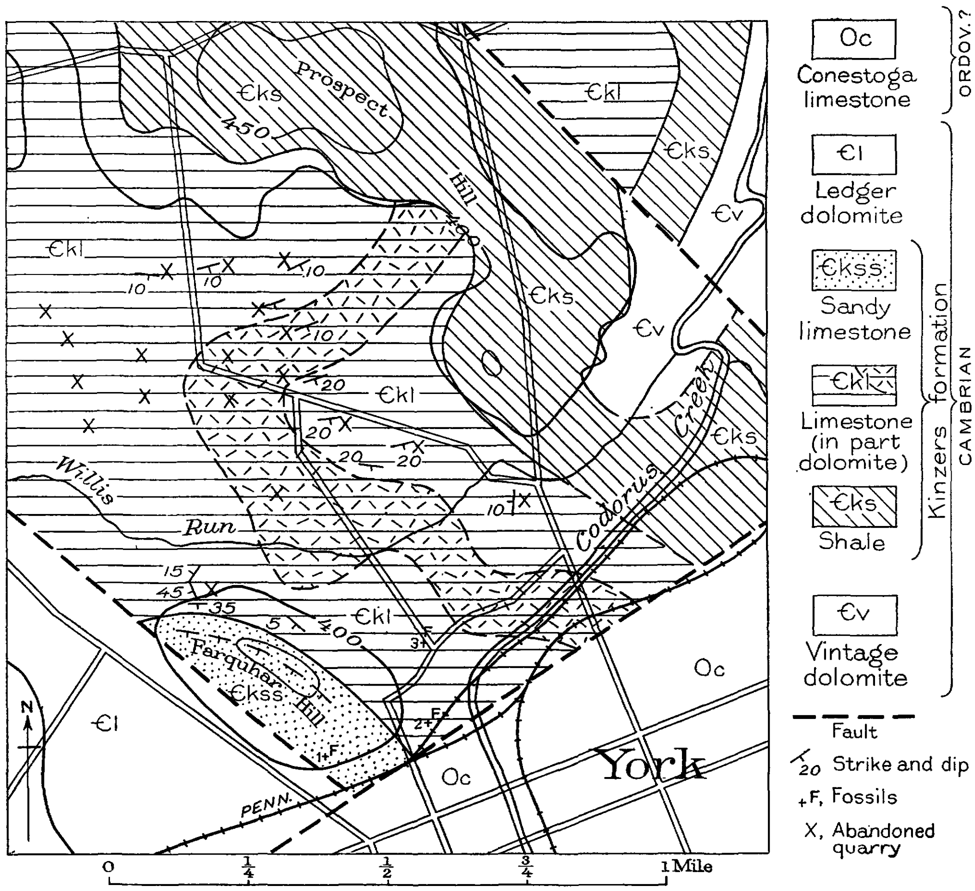


FIGURE 9.—Detailed geologic map of Farquhar Hill and Prospect Hill in York, showing distribution of pure calcic marble and dolomite in middle member of Kinzers formation. Shale on Prospect Hill is lower member, and sandy limestone forming Farquhar Hill is upper member. Fossil localities of Wanner and others in York: 1, Corner of North Penn and West North Streets; 2, Grant Alley and Gas House; 3, Cutcamp's quarry and Smith's lime kilns at Smith and Union Streets.

From the detailed sections of parts of the formation given on following pages, the general composition of the Kinzers formation in the Hanover-York district may be stated as follows:

General character of Kinzers formation in Hanover-York District

	Feet
Upper member: Earthy limestones; weather to soft buff tripoli and fine sandstone; generally fossiliferous, and interbedded with dark argillaceous thin-bedded limestone	125–180
Middle member: Thick white to mottled or spotted marble and granular limestone; some coarsely conglomeratic, containing Archaeocyathid reefs and minor amounts of dark thin-bedded argillaceous limestone; earthy generally fossiliferous limestone at base, weathers to buff tripoli	100–175
Lower member: Dark shale, with earthy limestone which weathers to buff tripoli at the base. (Shale is highly fossiliferous in Lancaster area)	100–150
	325–505

Because the sandy limestone near the top was believed to be the base of the Conestoga limestone, the underlying pure limestone beds in the Palmer Lime and Cement Co. quarry, the Laucks quarry, and other quarries near York were described previously [23] as part of the Ledger dolomite. Further stratigraphic work and the finding of additional fossils have proved that these pure limestones should be included in the middle member of the Kinzers formation.

In many places the mottled limestones in the middle member of the Kinzers are thick-bedded and very pure, containing little magnesium or other impurities, and are extensively quarried in the vicinity of York and Thomasville.

Northwest of York in the Willis Creek lowland, many old quarries are in this pure limestone. The purer high-calcium limestone has been quarried out, and the rock now exposed is mostly dolomite, which probably replaced pure limestone of the Kinzers, and limestone mottled with dolomite in process of replacement. The sketch map in figure 9 shows the writers' interpretation of this area. The dolomite in the quarries is massive bedded and resembles the Ledger, but the presence of the interbedded pure mottled white marble of the middle member of the Kinzers formation indicates that this rock is limestone of the Kinzers that apparently has been dolomitized, like that in the Palmer Lime & Cement Co. quarry in West York. The following composite section is based on exposures of the pure limestone beds of the Kinzers in this area:

[23] Stose, G. W., and Jonas, A. I., op. cit., Bull. 840, p. 28.

Composite section of the limestones in the middle member of the Kinzers formation in Willis Creek Valley northwest of York

	Feet
Middle member:	
Massive gray fine-grained dolomite (probably replaced limestone); some of it is oolitic and conglomeratic	20
White and some blue marble; partly oolitic and conglomeratic, with apparently siliceous dolomite matrix which weathers to a porous mass standing in relief	15
White and blue marble; oolitic in part	30
Massive pure white marble with few wavy dolomitic bands; weathers to granular surface	30
Granular white marble; some massive thick-bedded conglomerate; weathered surfaces have a thick dark porous coating	30
White marble, with blue bands; wavy dolomitic bands weather in relief	15
Marble (poorly exposed)	10
White marble, in part banded and mottled with blue	20
	170±
Lower member: Dark shale.	

Most of the marble layers are limestone and not dolomite.

Farquhar Hill (fig. 9) is composed of the sandy upper member of the Kinzers formation and is apparently underlain by the pure marble of the middle member which is exposed in an old quarry at the north end of the hill. The rock in this quarry is much broken and sheared and the structure appears to be a plunging anticline. The following section is exposed in the quarry:

Section in old quarry on north side of Farquhar Hill

	Feet
White marble	5±
Impure banded blue limestone; impure layers weather in relief	10±
Conglomerate of white marble fragments in blue and white banded and streaked marble	20±
Massive granular dolomite; in part oolitic	20±
Blue and white streaked fine-grained marble	30±
	85±

Farquhar Hill is apparently cut off on two sides by faults. The sketch map (fig. 9) shows locations where Wanner and others collected an interesting assemblage of Lower Cambrian fossils.

In the area south of West York the thick limestone of the middle member of the Kinzers formation has been extensively quarried by the Palmer Lime and Cement Co. The quarries are indicated on the sketch map of the West York area (fig. 10). A sketch plan and cross sec-

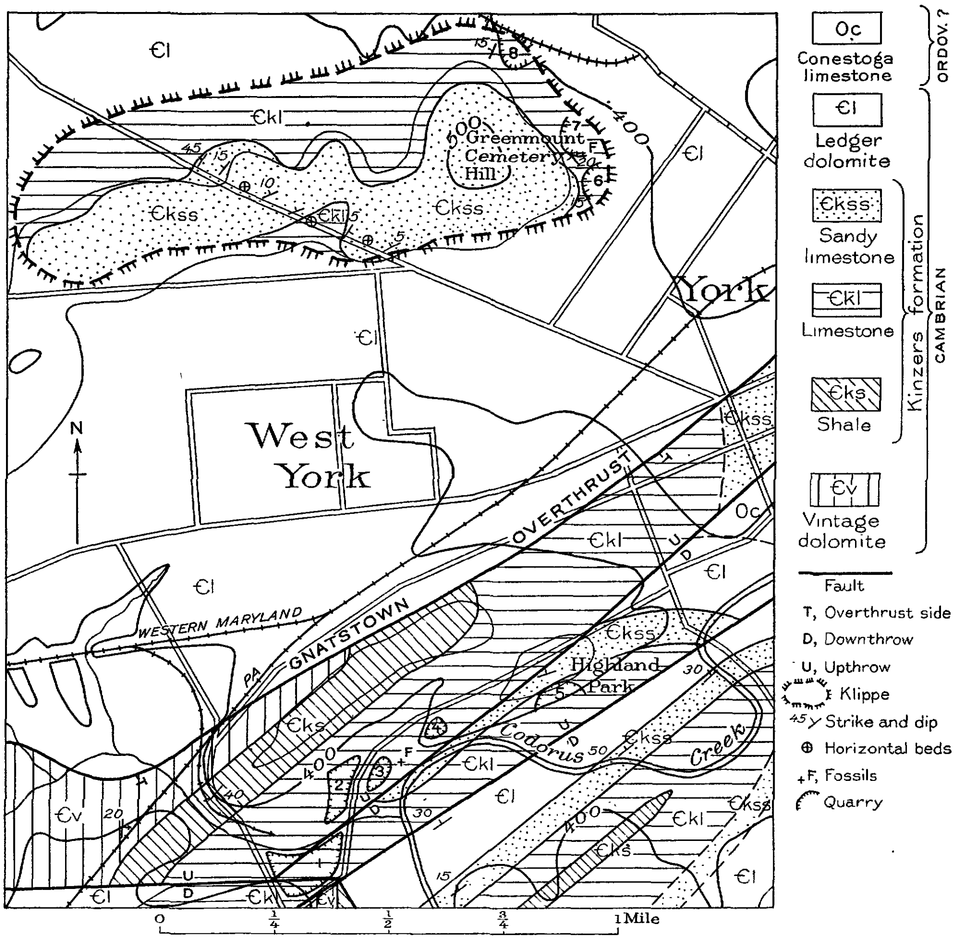


FIGURE 10.—Geologic map of West York and vicinity, showing detailed geology and structural interpretation. Fossils were collected by Wanner at point F. Location of quarries: 1 and 2, active quarries of Universal Gypsum & Lime Co.; 3, abandoned quarry of Palmer Lime & Cement Co.; 4, abandoned quarry; 5, active quarry of Eli Zinn Co.; 6 and 7, abandoned and active quarries of Eli Zinn Co.; 8, active quarry of York Stone & Supply Co.

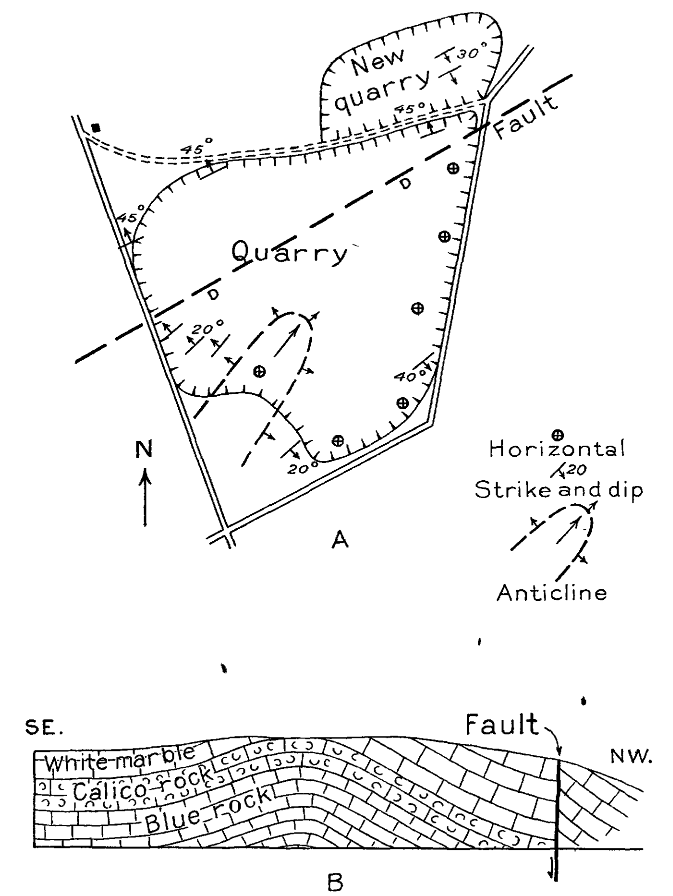


FIGURE 11.—Sketch of plan and section in quarry of Universal Gypsum & Lime Co. in West York: A, Plan showing general anticlinal structure of quarry rock and a fault cutting across the quarry; D, downthrown side. B, Generalized cross section of southwest face of quarry; scale twice that of map. All limestones are in middle member of Kinzers. Calico rock is marble mottled with magnesium carbonate.

tion of the large active quarry now operated by the Universal Gypsum and Lime Co. is shown in figure 11. The general structure is a gently plunging anticline cut by a fault which passes through the northern part of the quarry.

The limestone in the Universal Gypsum & Lime Co. quarry are in part magnesian and in places are completely altered to dolomite. A general section of the beds exposed in the quarry follows:

Section of limestones of the middle member of the Kinzers formation in quarry of Universal Gypsum & Lime Company

	Feet
Gray well-bedded dolomite and thin blue fossiliferous limestone (exposed northwest of plant)	15
Coarse granular dolomite; weathers to granular surface; forms top of north face of quarry; much thicker in places, owing to replacement of pure limestone by magnesium carbonate diagonal to the bedding	5
Blue and white streaked pure marble	5
Thick-bedded white sugary marble with a few dark coarsely crystalline blotches	20–40
White marble mottled with magnesian spots and bands (pl. 5, *B*, Calico rock; reported to contain 18 percent magnesium carbonate); magnesian spots weather in relief and to chalky white blotches	25±
Thick light-gray crackled dolomite; irregular bed at top of south face of quarry	10–20
Massive tough dark-blue mixture of limestone and dolomite; face and floor at south side of quarry	40±
	120–150±

In this quarry, pure high-calcium limestone grades upward through beds of mottled limestone to coarse granular dolomite, which forms the top of the north face of the quarry (pl. 5, *B*). Along joint fractures and associated brecciated zones in the pure limestone (fig. 12), the rock merges laterally into irregular masses of coarse-grained grayish dolomite. Obviously, circulating waters have gradually changed the original pure high-calcium limestone to dolomite. In places, pure dark-blue fine-grained high-calcium limestone that was not dolomitized has been metamorphosed to a coarse-grained white marble. At the border of such altered rock, a transition zone of mottled blue and white marble is composed of rounded residual masses of dark-blue limestone in white marble. The unaltered blue masses resemble pebbles in the coarse-grained marble, and the rock may be mistaken easily for a limestone conglomerate.

Coarse-grained dolomite, resulting from the addition of magnesium oxide and the recrystallization of the limestone, closely resembles the overlying Ledger dolomite; and the two dolomites cannot be distinguished except by the association of key beds. The coarse-

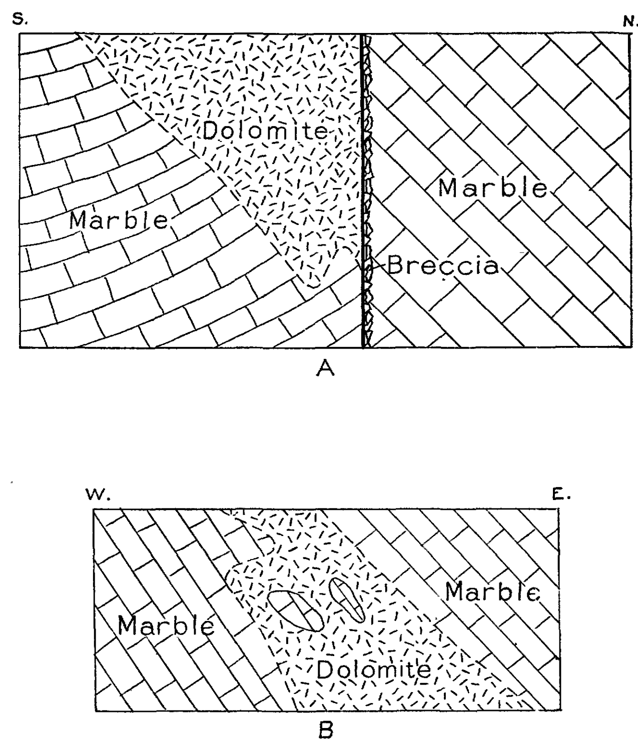


FIGURE 12.—Sketches showing dolomitization of limestone in quarry of Universal Gypsum & Lime Co. in West York: A, Brecciation and dolomitization of limestone adjacent to fault in west wall; B, Part of north wall of quarry showing irregular replacement of white marble by dolomite.

A. RETICULATELY WEATHERED ARGILLACEOUS BANDED LIMESTONE OF UPPER MEMBER OF KINZERS FORMATION IN RAILROAD CUT SOUTH OF QUARRY OF THOMASVILLE STONE & LIME CO.

Beds generally fossiliferous.

B. WEATHERED SURFACE OF MOTTLED LIMESTONE (CALICO ROCK) IN MIDDLE MEMBER OF KINZERS FORMATION, EXPOSED IN QUARRY OF UNIVERSAL GYPSUM & LIME CO. WEST YORK.

C. STRUCTURE IN LIMESTONES OF KINZERS FORMATION IN ABANDONED QUARRY OF PALMER LIME & CEMENT CO., WEST YORK.

Illustrated in figure 13. Thin black dolomitic bed, which bends downward, is apparently overlapped unconformably by horizontal beds.

D. FAULT IN KINZERS FORMATION EXPOSED IN QUARRY OF YORK VALLEY LIME & STONE CO., 6 MILES NORTHEAST OF YORK.

White marble thrust over dark argillaceous limestone and shale at left. Fault plane dips 60° S. (to the right).

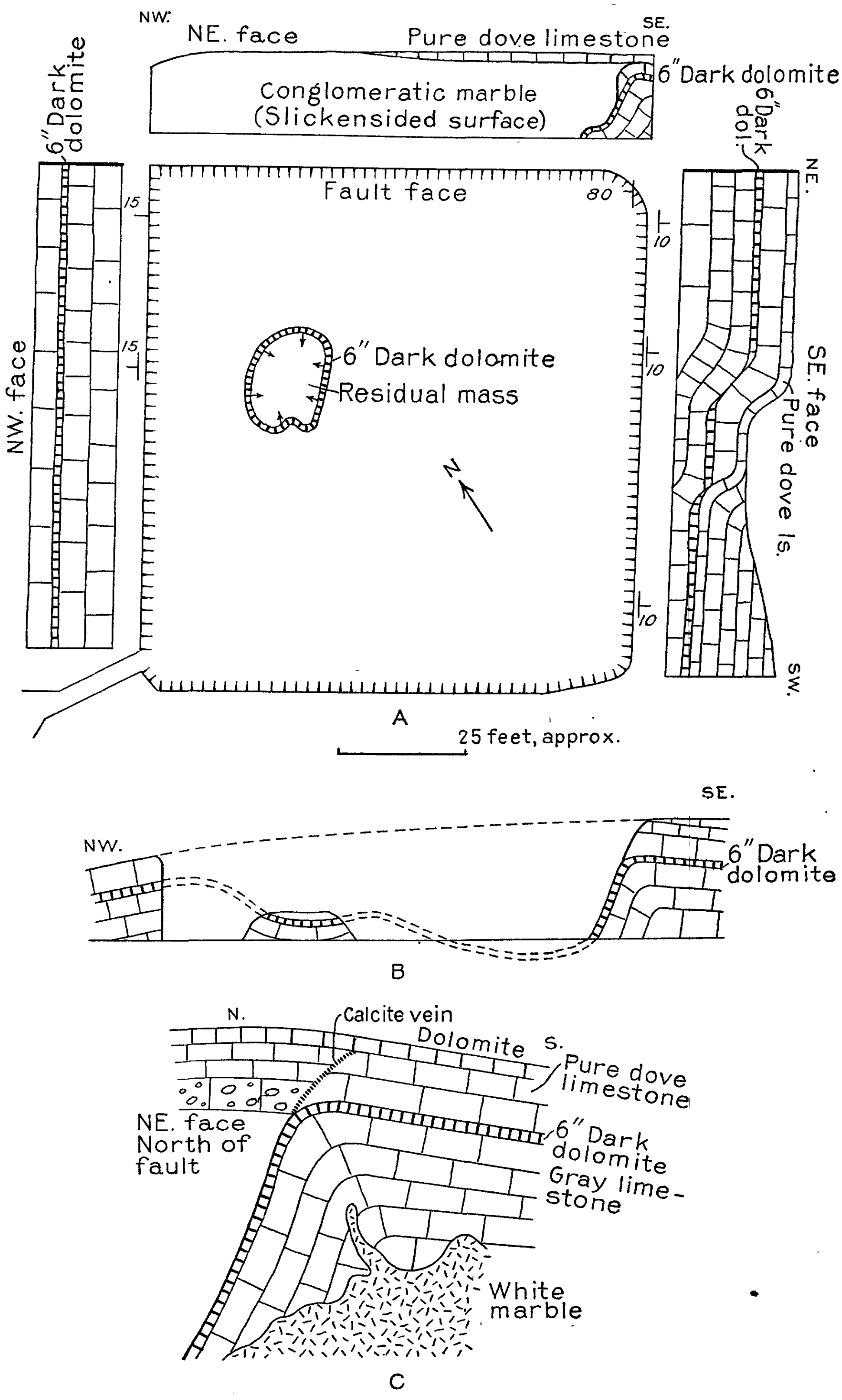


FIGURE 13.—Sketch of plan and sections in abandoned quarry (No. 3 in fig. 10) of Palmer Lime & Cement Co. in West York: A, Plan and walls showing down folding of thin layer of dark dolomite, a residual mass of which is preserved in bottom of quarry. Irregularity of sedimentation and overlapping of beds after folding or slumping are indicated in southeast face and in east corner, which is shown in sketch of northeast face. Northeast face of quarry seems to be a fault plane. B, Section diagonally through quarry to east corner. C. Detail of downfold in the thin dark dolomite bed in east corner of the quarry. Dove limestone at top seems to overlap downfolded beds. Gray limestone recrystallized into irregular patches of white marble shown at right.

grained dolomite in Willis Creek Valley north of York (fig. 9), as previously mentioned, closely resembles Ledger dolomite; but these rocks are intimately associated with high-calcium mottled marble of the Kinzers formation and are not separated from them by the sandy, earthy limestones usually present at the top of the Kinzers formation. For these reasons, the dolomite is mapped as part of the Kinzers.

the breccia and lapped over the older beds on the sides of the depression (fig. 13, A and B). Later, the blue limestone was in part recrystallized into a white marble, as shown in figure 13, C. A 6-inch layer of dark impure dolomite is the key bed in deciphering the structure. The southeast wall shows the irregularity of sedimentation. The 6-inch key bed of dark dolomite is apparently downfolded and thinned. The top bed of pure dove

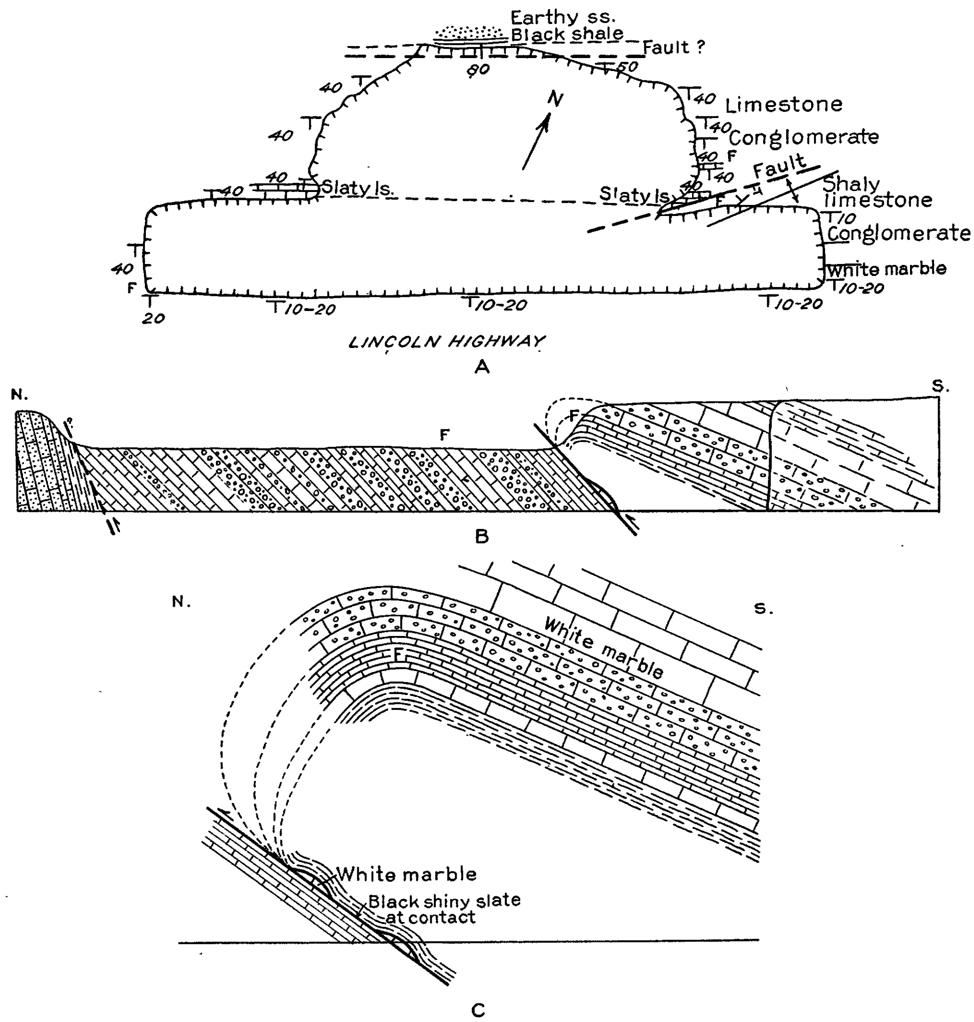


FIGURE 14.—Sketch of plan and sections in quarry of York Valley Lime & Stone Co., 6 miles northeast of York: A, Plan showing fault cutting east side of the quarry and another fault, which appears to form the back wall. Fossils were collected at two points marked F. B, Cross section of the quarry, scale three times that of plan, showing the faults and location of the fossiliferous bed. C, Detail of relationships at the fault contact on east side of quarry. Residual masses of white marble are enclosed in the slate at the contact.

In an abandoned quarry of the Palmer Lime and Cement Co. (No. 3 in fig. 10), near Codorus Creek and southeast of the road to Highland Park, are exposed some remarkable sedimentary structures, which apparently resulted from the caving and settling of beds during deposition. The lower beds of blue limestone apparently sank and the depression was filled with marble breccia, which is shown on the northeast wall of the quarry and was the chief rock formerly quarried. Pure dove limestone and dolomitic beds seem to have capped

limestone shows similar downfolding and overlapping of beds. The 6-inch key bed is sharply downfolded in an unquarried mass in the northeast corner. (See pl. 5, *C*.) The northeast wall exhibits a horizontally bedded limestone, veined, brecciated, stained red and cut by slickensided joints, which suggest a fault. As shown in the photograph, plate 5, *C*, the top bed of pure dove limestone appears to lap over this breccia, indicating deposition after the downfolding and the subsequent filling of the basin with breccia.

The purer limestone beds of the Kinzers formation are well exposed in the quarry of the York Valley Lime & Stone Co., 6 miles northeast of York and just north of Lincoln Highway (U S 30). A thrust fault passes through the quarry, and the limestones of the Kinzers formation to the south are overthrust on other limestones of the same formation. A sketch map of the quarry and a cross section are shown in figure 14.

Partial section of the Kinzers formation south of fault in York Valley Lime & Stone Co. quarry 6 miles northeast of York

	Feet
Thick granular, crystalline gray finely conglomeratic lime stone containing cystid plates and stem segments; interbedded thin, platy dark argillaceous limestone with earthy shaly partings, contains shells (*Nisusia festinata*) at west side of quarry	25
Black earthy finely conglomeratic limestone; coarsely oolitic to pisolitic; at base, pebbles of underlying white marble	10±
Massive-bedded white marble; basal beds, a conglomerate containing thin flat pieces and larger rounded fragments of white marble	30±
White to blue crystalline limestone and thin laminated limestone and conglomerate containing glassy quartz grains	20±
Black shale and interbedded thin-bedded granular, crystalline finely conglomeratic fossiliferous limestone containing *Nisusia festinata* with earthy, argillaceous ripple-marked partings; an anticline of this lower bed is overthrust on other limestone of the Kinzers formation; fault contact at east arm of quarry. (See fig. 14, *C* and pl. 5, *D*.)	25±
	110±

North of the fault in this quarry, thick alternating beds of limestone and limestone conglomerate were thought at first to belong to the Conestoga limestone,[24] but interbedded platy argillaceous limestones containing *Nisusia festinata* and *Bonnia* sp. indicate that the rocks are part of the Kinzers formation. At the north side of the quarry, between these limestone beds and the earthy sandstone at the top of the formation which lies north of quarry, there is apparently another fault. This section follows:

Partial section of middle member of the Kinzers formation north of fault in York Valley Lime and Stone Co. quarry

	Feet
Banded limestone with beds of granular, crystalline limestone containing cystid plates and stem segments; interbedded dark argillaceous limestone with shaly earthy partings contains *Nisusia festinata*	25±
Conglomerate composed of white marble pebbles in buff magnesian matrix containing cystid stem segments; also blue and white marble conglomerate	20±
Conglomerate composed of dolomite pebbles	20±
Dense granular dolomite containing scattered glassy quartz grains	20±
(Beds above exposed only on west side of quarry)	
Thin, platy fine-grained argillaceous limestone with slaty partings	20±
Thin-bedded dark argillaceous granular limestone containing *Nisusia festinata* and *Bonnia* sp., dark mud-lump earthy limestone, and some beds of limestone conglomerate	40±
Beds of coarse limestone conglomerate interbedded with dark-blue crystalline limestone, weathering white; and thin-bedded to shaly black earthy limestone or calcareous argillite	30±
Massive blue argillaceous crystalline limestone, weathering dull gray, and light granular crystalline limestone	20±
Limestone conglomerate composed of 1-inch granular crystalline marble pebbles in dark argillaceous limestone matrix; some dense dark crystalline limestone beds	30±
Thick black earthy crystalline limestone, weathering dull-gray, and lighter purer crystalline limestone with fine conglomerate composed of granular limestone pebbles and scattered glassy quartz grains	20±
	245±

[24] Stose, G. W., and Jones, A. I., op. cit. (Bull. 840), pp. 28 and 34.

Partial section of Kinzers formation in old quarry north of Philadelphia St., near Harrison St., in East York

	Feet
Bluish granular pitted limestone	15
Bluish limestone banded with dark argillaceous partings	3
Massive white saccharoidal marble and blue dense fine-grained limestone merging into one another (main quarry rock)	50±
Pure chalky white coarsely crystalline marble; lenticular; merges into argillaceous blue limestone that weathers to buff earthy shaly rock	5
Coarse conglomerate composed of large fragments of chalky white marble, pitted granular limestone, and slabby bluish granular limestone containing crinoid segments, in buff argillaceous finely conglomeratic matrix; fluorspar on shear planes	20±
Blue limestone with wavy buff argillaceous partings	10±
Pure granular pitted white marble with layer of blue and gray banded argillaceous limestone	15±
	188±

Another partial section of these beds in East York follows:

Partial section of Kinzers formation in A. M. Hake quarry at Philadelphia and Center Sts., East York

	Feet
Blue fine-grained thin-bedded limestone containing some quartz grains; rhythmically banded by thin argillaceous partings	30±
(Irregular contact with underlying marble owing to flow of the marble under intense compression)	
Thick-bedded white recrystallized marble mottled with dark gray	20±
Blue pure limestone with some fine argillaceous partings; thick beds of coarse conglomerate composed of white granular marble—some larger masses more than 10 inches thick—containing glassy quartz grains and crinoid stem segments, in dark limestone matrix	50±
Earthy limestone weathering to porous tripoli of buff to red color	2
Limestone and earthy weathering beds	10±
	112±

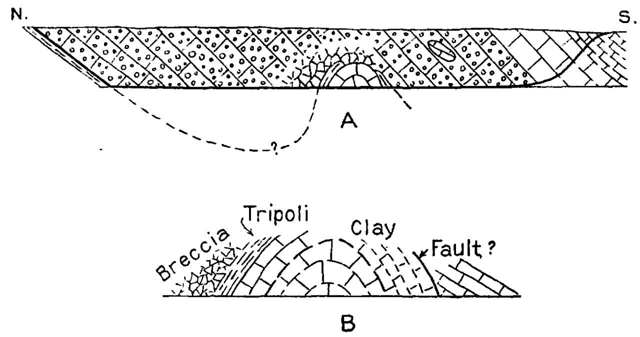


FIGURE 15.—Sections across the A. M. Hake quarry in East York: A, Sketch showing anticlinal structure exposed during the operation of the quarry in 1921; B, Detail of anticline.

The beds in this quarry appear to dip southward 20°–40°, but the quarry at a former stage showed an anticline in the middle. (See fig. 15.)

The Laucks quarry near Springdale School, 2 miles northwest of York, exposes 15 feet of white saccharoidal marble with few coarser dark blebs and, at the top, magnesian layers. Drill cores extending to a depth of 240 feet show similar white marble with gray mottling. This stone is reported to have an average of 95 percent or more $CaCO_3$. The marble from some of these cores was tested for ornamental stone and took an excellent polish.

Partial section of middle member of the Kinzers formation in the Eli Zinn quarry, north face of Greenmount Cemetery Hill (No. 8, fig. 10)

	Feet
White marble	30±
Dark argillaceous limestone	5±
Finely banded white marble containing spongelike fossils (archaeocyathids)	30±
Dark dense argillaceous limestone	15±
Massive white granular marble	30±
Dark wavy banded argillaceous limestone	30±
	140±

Partial section of the middle member of the Kinzers formation on road southeast of Kohlers Hill

	Feet
Blue and white mottled fine-grained marble ("leopard rock")	3
Concealed	10±
Dense earthy tripoli, and buff sandstone banded with black argillite streaks	10±
Concealed	20±
White crystalline marble	2
Concealed	15±
Pink to white fine-grained marble with knotty earthy banding ("leopard rock") which weathers to earthy network; contains *Salterella*	20±
Thick-bedded (3-foot beds) dense earthy tripoli; bluish dense earthy limestone where fresh; contains *Salterella*	10±
Light-blue limestone with wavy argillaceous banding; contains crinoid plates	10
Hackly gray to buff shale	15
Concealed	45±
Dark knotty magnesian mottled limestone	5±
	165±

Earthy fossiliferous limestone beds directly above the shale of the lower member are well exposed at an old quarry one-eighth of a mile north of Myers Mill, just east of the preceding section. The beds here are overturned.

Partial section of the Kinzers formation at quarry near Myers Mill, Middletown quadrangle

Middle member:	Feet
Dark-blue crystalline limestone; black shells of *Salterella* and fragments of trilobites abundant	5
Dark-blue shaly impure limestone weathering earthy (in small quarry below road and exposures above road)	30±
Dark limestone breccia cemented by buff dolomite; weathering results in lumpy conglomeratic appearance	5
Dark lenticular limestone with irregular buff earthy dolomite layers producing a wavy mottled banding and spotted appearance ("leopard rock")	10
Impure shaly gray limestone containing some earthy fossiliferous bands (in small quarry above road)	20±
Thick dense, tough earthy dolomite with black streaks; weathers to thick slabby porous tripoli; highly fossiliferous (top of quarry)	6
	76±

Concealed interval.
Lower member: Shale (on hill to south).

Fossiliferous earthy limestones are also exposed in a quarry in the extreme northwest corner of the York quadrangle on the highway (U. S. 111). The section, the beds of which are also inverted, follows:

Partial section of the Kinzers formation, northwest corner of York quadrangle

Middle member:	Feet
Black crystalline limestone; black shells of *Salterella* and fragments of trilobites abundant	10
Dark shaly limestone (poorly exposed)	20±
Blue limestone (quarried); largely mottled and wavy banded with argillaceous impurities (in part white spotted marble or "leopard rock") and some blue pure limestone	40±
Tough yellow earthy dolomite with black streaks and thick tripoli beds; fragments of trilobites and other fossils abundant	10±
	80±

Concealed interval.
Lower member: Shale (on hill to south).

Partial section of middle member of the Kinzers formation in Eli Zinn & Co. quarry on east face of Greenmount Cemetery Hill (No. 7, fig. 10)

	Feet
Dense impure limestone; weathers to buff tripoli and earthy sandstone; contains trilobites and brachiopods	2
Blue and white marble with magnesian layers that weather into wavy bands; at base, "leopard rock" and conglomerate composed of large white marble blocks and containing cystid plates	6
Earthy light-blue dense limestone; weathers to dense tripoli	9
Banded light-gray magnesian limestone in 2 thick beds; irregular fucoid-like magnesian banding	20

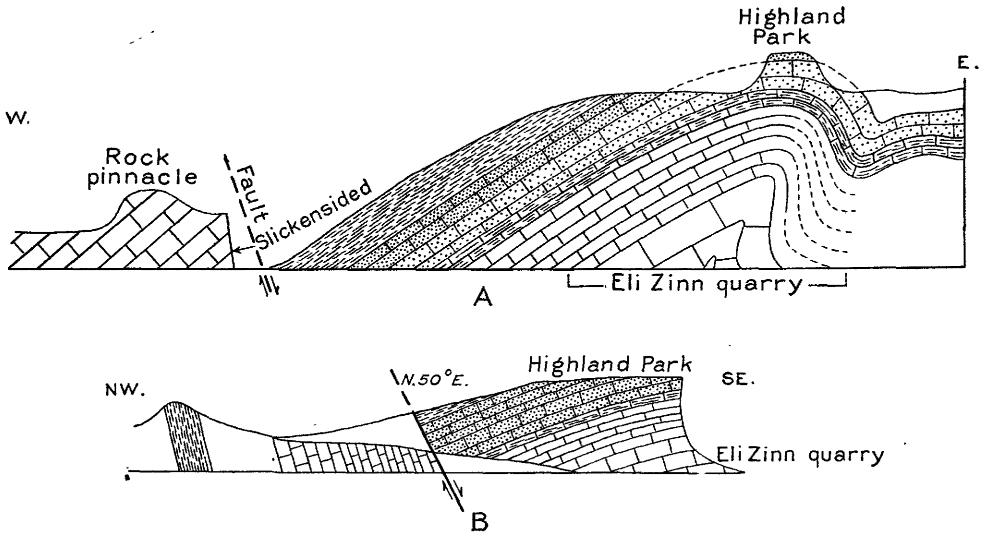


FIGURE 16.—Sections along Codorus Creek at the Eli Zinn quarry in southern part of York: A, Sketch of north bank of the creek. Sandy beds of upper member of Kinzers formation cap Highland Park Hill at top of quarry, which exposes an anticline of the middle member. Coarse-grained marble of middle member makes the rock pinnacle west of fault. B, Cross section through quarry, showing fault north of quarry.

	Feet
Dark impure limestone with buff banding in 1- to 2-inch beds; weathers to argillite	15
Light-gray fine-grained marble in 2-inch beds; weathers to blue marble mottled with buff magnesian layers and coarse granular upper surface	12
Massive light-gray granular, crystalline dolomite containing dark specks (probably replaced limestone)	15
	79

Section of part of Kinzers formation in old quarry on north slope of Farquhar Hill in York

	Feet
Upper member: Hackly buff earthy shale, slabby sandstone, and porous tripoli (forms top of hill)	20±
Middle member:	
White marble (largely concealed)	30±
Blue limestone with magnesian mottling which weathers in relief	10
Wavy banded, white, pink, and blue marble, in part conglomeratic; dolomite at top	15
Rounded white marble residual masses in dolomite matrix	2
Light-gray massive granular dolomite (probably a replaced limestone).	
	57±

The Eli Zinn Co. quarry on Codorus Creek, south of Highland Park in the southern part of York (No. 5 in fig. 10), exposes the upper part of the Kinzers formation. An anticline in the quarry brings up 20 feet of pure dove-colored marble, which underlies 60 feet of thick-bedded banded blue agrillaceous limestone, both belonging to the middle member of the Kinzers. (See fig. 16.) About 30 feet of light and dark rhythmically banded earthy, sandy, and argillaceous limestones, containing abundant bright pyrite cubes, cap the quarry and are overlain by 20 feet of black platy slate and banded sandy shale. A fault is exposed in the stripped area just west of the quarry. (See fig. 16, *B*.) Wanner reported excellent specimens of trilobites (*Olenoides* cf. *O. Marcoui* Whitfield) from loose pieces of slabby sandstone west of the fault. Walcott [25] described the fossils and referred to the quarry as the Highland Park locality.

Partial section of Kinzers formation in Eli Zinn & Company quarry, Codorus Creek, south of Highland Park in West York

	Feet
Upper member:	
Black, banded earthy shale	20±
Dense dark-banded glistening argillaceous sandy limestone; weathers to buff-banded earthy sandstone blocks	10
Thin-bedded dark nodular to shaly limestone, banded with impurities; contains pyrite cubes	10
Dense, tough light-blue, banded finely siliceous limestone; weathers to fine buff sandstone	8
	48±
Middle member:	
Dark-gray argillaceous limestone with gray magnesian banding; lighter gray below	52
Very thin-bedded dark glistening slaty limestone; weathers to shaly fragments	8
Gray and white mottled marble	20
	80

A section of the upper sandy member of the Kinzers formation along the Dover road over the Greenmount Cemetery Hill follows. The sketch (fig. 17) shows the minor folding of these beds.

[25] Walcott, C. D., Cambrian rocks of Pennsylvania, U. S. Geol. Survey Bull. 134, p. 18, 1896; and personal communication from A. Wanner.

Partial section of Kinzers formation along road on northwest slope Greenmount Cemetery Hill, 1 mile north of West York

	Feet
Upper member:	
Buff dense, tough tripoli or fine sandstone; banded near top; at base, thicker denser sandstone beds, 3 to 5 feet thick, derived from the weathering of light blue fine-grained quartzose limestone	20
Buff porous blocky sandstone (surface of hill covered with blocks)	5±
Dark earthy to sandy shale	10±
	35±

Middle member: Thick fine-grained white marble and dark dolomite.

The sandy beds of the upper member of the Kinzers formation are exposed also on another hill two miles southwest of West York.

Partial section of Kinzers formation along road on hill north of Lincoln Highway at Hellam, Middletown quadrangle

	Feet
Conestoga limestone:	
Coarse limestone conglomerate	5±
Kinzers formation:	
Upper member:	
Buff tripoli; derived from earthy dolomite	20±
Black banded dry earthy slate; contains small pyrite cubes in places	20±
Slabby tough calcareous sandstone, buff colored, banded, and mottled with dark gray; thin black argillaceous slaty partings (makes low ridge)	30±
	70±

Partial section of Kinzers formation in Stoners quarry 1 mile east of Columbia, Lancaster quadrangle

	Feet
Kinzers formation:	
Upper member:	
Even-layered dark calcareous shale or argillite; weathers to porous light-weight bony, platy shale	3
Coarsely granular marble; weathering shows round limestone pebbles at base	4
Earthy dolomite; weathers to buff bony tripoli enclosing marble pebbles	3
	10
Middle member:	
Coarsely granular glistening dark and light mottled marble; weathering shows round pebbles	20
Shaly dark limestone	5
Light-gray massive limestone, and conglomerate of granular gray limestone in dark limestone matrix	20±
Thin-bedded dark argillaceous limestone with crenulated shiny argillaceous partings, and granular limestones in beds 4 inches thick	20±
	65±

The Roy Bittinger quarry, west of Spring Grove, shows normal faulting, folding, and overthrusting (fig. 18 and pl. 6, *A* and *B*); and good specimens of trilobites (*Bonnia* sp.) were obtained in some of the beds. Another fault, not shown in the sketch, is exposed in the railroad cut east of the quarry. The quarry is in massive light-gray mottled crystalline limestone, overlain by thin-bedded dark argillaceous limestone with thick black carbonaceous shale partings and thin shale beds that show wavy bedding and ripple marks. Some of the thin-bedded rock is crystalline and fossiliferous. At the west side of the main quarry, the shale and thin-bedded argillaceous limestone are faulted down along a nearly vertical plane. At the east side of the quarry, an overturned anticline of the thin-bedded limestone is thrust over the thick beds. (See fig. 18.) West of the main quarry, recent stripping has exposed another nearly vertical fault (fig. 18, A). Trilobites have been obtained in thin beds of limestone at this locality.

Partial section of Middle member of Kinzers formation in Roy Bittinger quarry west of Spring Grove

	Feet
Dark-banded calcareous slate in rhythmically repeated 3-foot beds with ripple-marked surfaces and black carbonaceous partings; upper beds 6 inches thick; broken by diagonal cleavage dipping eastward	25±
Dark calcareous shale and interbedded thin crystalline fossiliferous limestones	4
Dark argillaceous limestone with black shale partings	4
Massive light and dark mottled granular, crystalline marble; top layer has wavy surface coated with black carbonaceous film	20
	53±

At the J. E. Baker quarry at Thomasville, the pure limestone of the middle member contains many needle-like crystals of quartz which in places on the surface weather out into dense nests of crystals (pl. 6, *C*).

AGE AND CORRELATION

The Kinzers is the most fossiliferous formation in York County. Fossils have been collected from all three members of the formation. A few feet of earthy beds at the base of the shale of the lower member contain the lowest fossiliferous horizon. Fossils obtained by the writers and C. E. Resser from these beds at Donnerville, Lancaster County, have been identified by Resser as *Bonnia senecta?* (Billings) and *Olenellus* sp. (fragments).

The shale of the lower member is highly fossiliferous, especially in the vicinity of Lancaster. A complete list with descriptions and plates of fossils from the shale member in Lancaster and York counties is given by Resser and Howell in a recent publication.[26] These fossils were collected from four localities in Pennsylvania, three of which are in Lancaster County. The fourth is located 2 miles north of the square in York, where fossils were collected largely by C. D. Walcott,

[26] Resser, C. E., and Howell, B. F., Lower Cambrian *Olenellus* zone of the Appalachians: Geol. Soc. Am. Bull., vol. 49, pp. 205–248, 1938.

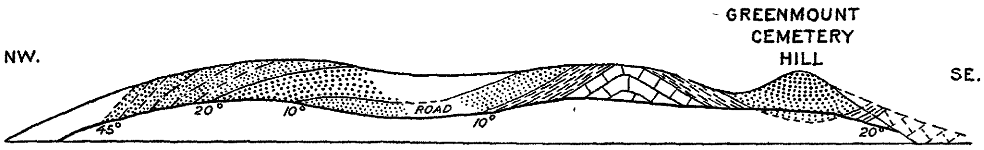


FIGURE 17.—Section along Dover road over Greenmount Cemetery Hill, showing structures in sandy limestone of upper member of Kinzers formation.

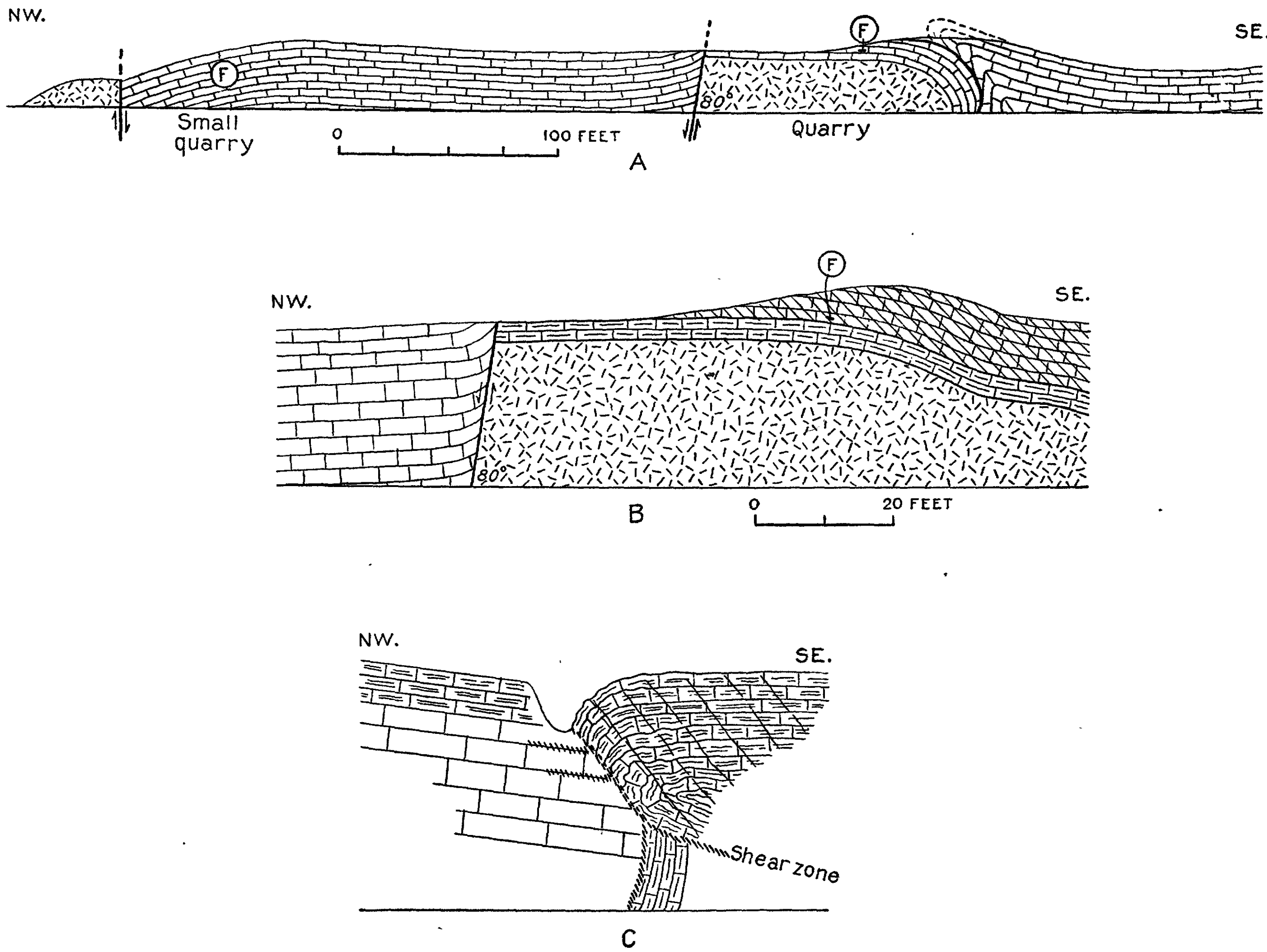


FIGURE 18.—Sections in Roy Bittinger quarry west of Spring Grove: A, Sketch of north bank of Codorus Creek, showing two normal faults and a thrust fault. At points marked F, fossils were collected in thin-bedded crystalline limestone overlying massive granular marble of middle member of Kinzers. B, Detail at the normal fault exposed in quarry. The massive-bedded marble is overlain by dark argillaceous limestone and shale, and this by thin-bedded fossilerous limestone, which is cut by diagonal cleavage that dips southeast. C, Detail of structure at thrust fault exposed at right edge of quarry.

Charles Schuchert, and Atreus Wanner many years ago. Most of the species, however, occur also at the localities near Lancaster. The fossils found 2 miles north of York include the following:

- Lepidocystis wanneri Foerste
- Salterella acervulosa Resser and Howell
- Hyolithes wanneri Resser and Howell
- Eoagnostus roddyi Resser and Howell
- Olenellus similaris Resser and Howell
- Olenellus alius Resser and Howell
- Olenellus wanneri Resser and Howell
- Paedeumias glabrum Resser and Howell
- Paedeumias yorkense Resser and Howell
- Paedeumias eboracense Resser and Howell
- Wanneria walcottana (Wanner)
- Esmeraldina macer (Walcott)
- Bonniella yorkensis Resser and Howell
- Anomalocaris lineata Resser and Howell

Resser and Howell regard this fauna as the equivalent of that from the lower shales of the Parker slate exposed in the Parker quarry, near Parker Cobble, Vt. The Parker slate was first described and named by Keith.[27] Schuchert [28] gives a more complete description

[27] Keith, A., Stratigraphy and structure of northwestern Vermont: Jour. Wash. Acad. Sci., vol. 22, p. 371, 1932.

[28] Schuchert, Charles, Cambrian and Ordovician stratigraphy of northwestern Vermont: Amer. Jour. Sci., 5th ser., vol. 25, pp. 362–364, 1933.

of the formation, including the impure dolomites and reef limestones above the slate, and lists the fossils from the Parker slate.

Resser and Howell [29] correlate the shale member of the Kinzers formation with the Rome formation because both contain *Olenellus* and *Hyolithes*. The writers' objection to this correlation is fully stated in their paper[30] on the Austinville area, Va., and will be restated in the discussion of the Great Valley facies and its southeastern limestone facies. (See p. 34.)

Just above the shale, earthy limestones at the base of the middle member have yielded fossils near Myers Mill in the Middletown quadrangle, from the quarry at the northwest corner of the York quadrangle, and near Rohrerstown in the Lancaster quadrangle. Collections by the writers and others were identified by Resser and include:

Nisusia festinata (Billings)
Kutorgina cingulata (Billings)
Paterina bella (Billings)
Kootenia marcoui (Whitfield)
Dawsonia parkeri (Walott)
Rustella edsoni Walcott
Yorkia wanneri Walcott
Kochiella? Pennsylvanica Resser
Periomella roddyi Resser
Ptychoparella lancastra Resser
Ptychoparella sp.
Hyolithes sp.
Olenellus sp.
Bonnia bubaris Walcott
Bonnia capito Walcott
Cystid plates
Salterella sp.

Fossils collected by the writers from a higher argillaceous limestone in the middle member at the quarry of the York Valley Lime & Stone Co., 6 miles northeast of York, were identified by Resser as *Kochiella* sp., *Agnostus* sp., *Ptychoparella* sp. [*Ptychoparia*], *Prozacanthoides* sp., *Nisusia festinata* (Billings), *Lingulella* sp., and a phyllopod resembling *Schaefferia.* G. A. Cooper and the writers also collected *Kootenia* sp. from these beds.

The purer limestones and marbles of the middle member, extensively quarried in the area, are generally unfossiliferous, but the writers have observed archaeocyathid reefs in these beds at the Forry Lauck's quarry just south of Lauck School, at Eli Zinn quarry on the north slope of Greenmount Cemetery Hill, and in the quarry of the Universal Gypsum and Cement Co. in West York. Similar archaeocyathid reefs occur in pure marble and limestones of the same age near Austinville, Va., (see p. 33).

The writers collected fossils from the earthy, sandy beds in the upper member of the formation at many places indicated on the geologic map of the district, and at several places in the adjoining Middletown quadrangle. Fossils collected a quarter of a mile north of Strickler Station were identified by Resser as *Agnostus*, *Bonnia*, *Nisusia*, an unnamed phyllopod, and *Salterella.* Those collected on the road to Highmount north of Lincoln Highway, 1½ miles northeast of the center of Hellam, were identified as *Eoagnostus*, cystid plates, and an alga resembling *Morania.* Schuchert reported *Acrothele decipiens* from this locality. The writers' largest collection of fossils at this horizon was obtained from exposures on the Western Maryland Railroad, south of the quarry of the Thomasville Stone and Lime Co. These were identified by Resser as *Syspacephalus?*, *Kochiella*, *Nisusia*, *Hyolithes*, cystid plates, and a *Discina* like form probably *Paterina. Nisusia*, *Yorkia*, and undetermined trilobites were collected at Sunnyside Station on the York Electric Railroad half a mile southwest of Bair. In the limestone quarry of Roy Bittinger, at the railroad southwest of Spring Grove, good specimens of trilobites were collected by the writers and by Josiah Bridge and were identified by Resser at *Bonnia* cf. *B. capito*. *Paterina* sp. was also collected here. In a small quarry 1 mile southeast of Thomasville, *Nisusia*, *Kootenia*, and *Ptycoparella* were collected. In the quarry on the east side of Greenmount Cemetery Hill, *Nisusia*, *Kutorgina*, and cystid plates were collected; and 2 miles southwest of West York, *Periomella* sp., and *Eoagnostus* sp. were obtained.

About 1895 Atreus Wanner, Charles Schuchert, and C. D. Walcott collected trilobites and other fossils from sandy shale near the top of the Kinzers formation in the northern part of York. These fossils were reported from three localities: in Grant Alley near the plant of the York Gas Co., at Cutcamp's quarry and Smith lime kiln north of Cottage Hill Road, and at Penn and North Streets. (See fig. 9.) Only the Grant Alley locality can be studied at present because of the city's development, and the writers have recently collected a number of fossils from this locality. The fossils in the following list from this horizon were identified by Resser:

Acrothele decipiens (Walcott)
Acrothele yorkensis (Walcott)
Poliella [Bathyuriscus] bala (Walcott)
Agnostus sp.
Ptychoparella sp.
Chancia n. sp.
Chancelloria yorkensis (Walcott)
Periomella yorkensis Resser
Prozacanthoides sp.
Cystid plates

In the report on the Middletown quadrangle,[31] the writers assigned these fossils to the Ledger dolomite

[29] Resser, C. H., and Howell, B. F., op. cit., p. 205, 1938.

[30] Stose, G. W., and Jonas, A. I., A southeastern limestone facies of Lower Cambrian dolomite in Wythe and Carroll Counties, Va.: Virginia Geol. Survey Bull. 51-A, pp. 20-22, 1938.

[31] Stose, G. W., and Jonas, A. I., Geology of the Middletown quadrangle, Pa.: U. S. Geol. Surv. Bull. 840, p. 29, 1933.

A. VERTICAL NORMAL FAULT IN ROY BITTINGER QUARRY, SPRING GROVE.

Dark thin-bedded argillaceous limestone at left is faulted down relative to thick-bedded granular limestone. Both limestones are part of the Kinzers formation. (See fig. 18, A and B.)

B. THRUST FAULT IN ROY BITTINGER QUARRY, SPRING GROVE.

Dark argillaceous limestone thrust westward (to left) over thick-bedded granular limestone. (See fig. 18, C.)

C. NESTS OF NEEDLELIKE CRYSTALS OF SMOKY QUARTZ ON WEATHERED SURFACE OF LIMESTONE IN KINZERS FORMATION IN SOUTH QUARRY OF J. E. BAKER CO., THOMASVILLE.

because Resser considered them to be high in the Lower Cambrian or in the Middle Cambrian.

Similar fossils, including *Poliella bala*, were collected by the writers from the upper part of the Kinzers formation in the Pennsylvania railroad cut at Dillerville, west of Lancaster.

All the fossils collected from the Kinzers formation indicate Lower Cambrian age. The name, Kinzers formation, has been recently extended [32] to a fossiliferous series, which is lithologically and faunally similar, in a small area south of Austinville, Va., on the southeastern edge of the Great Valley. The fossils collected there are listed on pages 15–18 of the bulletin referred to. The fauna from Fossil Point in the Virginia area is described by Resser [33] as similar to that in the middle member of the Kinzers formation in the vicinity of York. The rock at Fossil Point is a pure white crystalline limestone, with thin earthy-weathering layers containing archaeocyathid reefs in several beds and abundant Lower Cambrian brachiopods and trilobites. According to Resser fossils, including *Poliella bala*, collected from the top of the middle member of the Kinzers in the Virginia area, possibly belong to the same fauna as those from the uppermost earthy-weathering sandstones of the upper member in Grant Alley near York. Resser states also that the *Bonnia* fauna of the Kinzers near York and southeast of Austinville, Va., is the same as that from the Forteau [34] limestone of Bonne Bay, Newfoundland.

LEDGER DOLOMITE

NAME AND DISTRIBUTION

The Ledger dolomite was named from the village of Ledger, Lancaster County, Pa., where it is typically exposed and is overlain by the Elbrook formation north of Lancaster. In the Hanover-York district this dolomite is not found everywhere above the Kinzers formation because in many places the Conestoga limestone overlaps on the Kinzers formation. The Ledger is best exposed in the area north of York and southwestward in the broad limestone valley nearly to Thomasville. Another large area with few outcrops makes the lowland to the east, south, and southwest of Spring Grove. North of Hellam Station a narrow lenticular band of the formation is exposed between the top of the Kinzers and the base of the overlapping Conestoga limestone.

CHARACTER AND THICKNESS

The Ledger is everywhere a coarse-grained granular pure dolomite, and is free from silica and other impurities, except in one cherty layer. The dolomite is very thick bedded, coarse grained, and of light-gray color, mottled in places with dark spots. It weathers to a characteristic deep-red granular soil. The chert horizon is near the top of the formation and is mapped in the Hanover quadrangle from West York to beyond Botts. Residual porous masses of chert occur in the deep-red dolomitic soil and in places are so concentrated as to make hills. The beds above the chert horizon are deeply weathered but are of the same character as the dolomite below the chert.

The dolomite is so pure that elsewhere in the region it is extensively quarried for magnesian products, but has not been utilized for this purpose in this district or in adjacent areas. The old quarry of the Dolomite Products Co. at Shreiner, 3 miles northwest of Lancaster, is the nearest locality where it has been quarried for magnesian products. At Billmeyer, on the Susquehanna River in the Middletown quadrangle, J. E. Baker and Co. quarry and deadburn the dolomite for the lining of basic open-hearth furnaces. Large quarries in the Ledger dolomite are operated by the Warner Company at Cedar Hollow and Mill Lane, 5 miles south of Phoenixville; and there are many more quarries in the vicinity of Schuylkill River south of Norristown.

The total thickness of the formation can not be determined in the Hanover-York district as the top is not exposed. North of Marietta in the Middletown area, where the Elbrook limestone overlies the Ledger dolomite north of the Chickies overthrust, a thickness of 1,200 feet has been computed from the width of the outcrop and average dip.

AGE AND CORRELATION

No fossils have been found in this formation in this district. Fossils previously mentioned as occurring in the Ledger dolomite are now known to come from the Kinzers formation. The pure limestones with impure shaly beds, from which *Nisusia festinata* was collected near Bittinger, northwest of Hanover, were described [35] as Ledger dolomite in earlier reports but are now assigned to the Kinzers formation.

The writers believe the Ledger dolomite is equivalent to the upper part of the lithologically similar Tomstown dolomite of the Chambersburg region in the Appalachian Valley. Throughout the valley, dolomite or limestone in which fossils are scarce or absent represent the Kinzers and cannot be distinguished from the enclosing carbonate formations. The Tomstown dolomite in the Appalachian Valley is overlain by the Lower Cambrian Waynesboro formation which is not present

[32] Stose, G. W., and Jonas, A. L., The southeastern facies of Lower Cambrian dolomite in Wythe & Carroll Counties, Virginia: Virginia Geol. Survey Bull. 51–A, 1938.

[33] Resser, C. E., Cambrian system (restricted) of the Southern Appalachians: Geol. Soc. America Special Papers, No. 15, pp. 24–25, 1938.

[34] Schuchert, Charles, and Dunbar, C. O., Stratigraphy of western Newfoundland: Geol. Soc. America Mem. 1, pp. 18–32, 1934

[35] Stose, G. W., U. S. Geol. Survey Atlas Fairfield and Gettysburg Folio (No. 225), p. 8, 1929; Knopf, E. B., and Jonas, A. I., U. S. Geol. Survey Bull. 799, p. 54, 1929; Jonas, A. I., and Stose, G. W., Pennsylvania Topog. and Geol. Survey Bull. 168, p. 32, 1930.

in the Hanover-York Valley. The Ledger dolomite, therefore, is assigned to the Lower Cambrian.

The Vintage dolomite, Kinzers formation, and Ledger dolomite are regarded collectively as the equivalent of the Tomstown dolomite of the Great Valley. These three Lower Cambrian formations represent a southeastern fossiliferous depositional facies which was developed only in the area south of the Welsh Mountain, Chickies, Hellam Hills, and Pigeon Hills anticlines. Close folding and overthrusting have brought these fossil-bearing strata closer to the dolomite facies of the Great Valley. Fossiliferous facies, similar in lithologic character and fauna to the Vintage dolomite, Kinzers formation, and Ledger dolomite, are recognized [36] also southeast of Austinville, Va., where they are equivalent to the Lower Cambrian dolomite (Shady) of the Great Valley and represent different sedimentary facies deposited on the southeast border of the main Appalachian geosyncline. Later thrust faulting carried this southeastern facies northwestward so that it now rests on the typical Shady dolomite.

ORDOVICIAN (?) SYSTEM

CONESTOGA LIMESTONE

NAME, DISTRIBUTION, AND UNCONFORMABLE RELATIONS

The Conestoga limestone is the only formation of probable Ordovician age present in the area. It was named from Conestoga Creek in the vicinity of Lancaster, where the formation is typically exposed and where its unconformable relationship to the underlying formations are well shown. Valleys are generally formed in this limestone, which occupies most of the broad, flat lowland from York northeastward to Wrightsville and underlies the larger part of the city of York. The outcrop of the formation does not extend to West York nor cross Codorus Creek, for at that locality an anticline exposes older limestones which separate the formation from another large area of Conestoga limestone extending southwestward from Hoke School and south of Bair and tapering out 2 miles east of Spring Grove. Hanover is in the midst of a third large area of Conestoga limestone which extends southward from the foot of the Pigeon Hills nearly to the Stoner overthrust. East of Hanover narrow areas of the formation are exposed in valleys bordered by Harpers phyllite of the Stoner overthrust block.

The Conestoga limestone is unconformable on the underlying formations and therefore transgresses their outcrops. Northeast of York, in most places on the north and south sides of York Valley, the Conestoga rests on the Kinzers formation, but it overlies Ledger dolomite north of Hellam Station and in the quarries north of Wrightsville. (See fig. 8.) South of York the Conestoga overlies Ledger dolomite exposed in small uplifts within the valley; and east of Spring Grove it rests also on Ledger dolomite. The Conestoga limestone is not preserved in the valley for several miles southwest of Spring Grove. On the south side of the Hanover lowland and at Penn Grove, the limestone overlies the lower shale member of the Kinzers, but north of York Road it appears locally to overlap the Vintage dolomite and to overlie the Antietam quartzite.

In the northern part of the East Prospect syncline, the Conestoga limestone rests on the lower shale member of the Kinzers; in the southern part, it overlaps the Vintage dolomite and rests on the Antietam quartzite from a point north of East Prospect to east of Margaretta Furnace, where the formation is cut off by the Cabin Creek overthrust. Small outcrops of residual black slate in the lowland 1 mile south of Margaretta Furnace may represent the Conestoga limestone overlying unconformably Vintage dolomite and Antietam quartzite.

Three narrow flat-bottomed valleys occur within the Antietam quartzite area on the south side of the Mount Pisgah anticline; one south of Delroy, another south of Golden along Kreutz Creek, and the third north of Ore Valley. No rocks crop out in the valleys; but as they are bordered by deposits of brown iron ore and contain limestone soil and small black slate fragments, they are believed to be underlain by limestone—presumably the Conestoga, because the black calcareous slate fragments found in the soil are a characteristic weathering product of this formation.

The Conestoga limestone occupies two narrow valleys in the Jefferson syncline. The northern and longer valley extends from Middle Branch of Codorus Creek southwest to Valley Junction. The limestone overlies Antietam quartzite, except north of Smyser Station where a small area of Vintage dolomite is exposed between the Conestoga and the Antietam quartzite. The southern valley extends from Smyser Station southwestward to Sinsheim and is separated from the northern valley by an anticline of Antietam quartzite. The trace of the Martic overthrust is the south border of the limestone in the southern valley. Along West Branch is another syncline likewise striking southwestward and probably containing Conestoga limestone which overlies Antietam quartzite except on the south side where the Martic overthrust cuts off the formation.

CHARACTER AND THICKNESS

The Conestoga limestone in the type locality near Lancaster is largely a thin-bedded crystalline blue limestone with dark argillaceous partings (pl. 7, *A*). It is generally closely folded, and in many places pronounced transverse cleavage obscures the bedding. The lower part of the formation consists of thick-bedded granular limestones, with coarse limestone conglomerate

[36] Stose, G. W., and Jonas, A. I., The southeastern facies of Lower Cambrian dolomite in Wythe and Carroll Counties, Virginia: Va. Geol. Surv. Bull. 57–A, 1938.

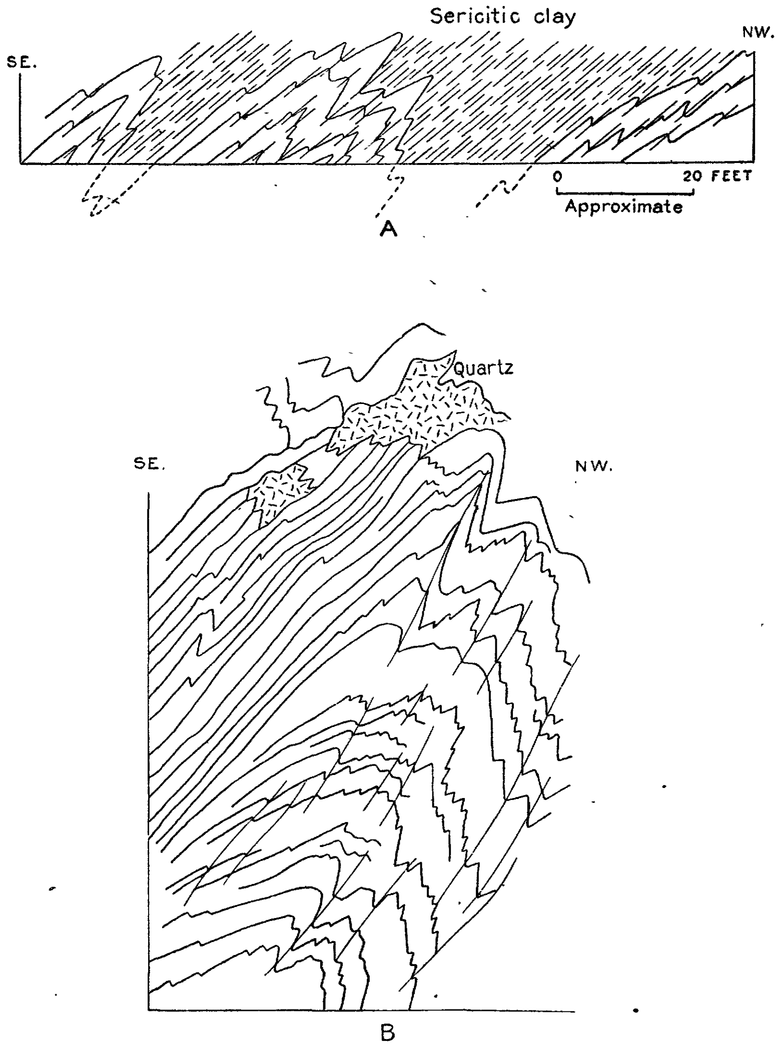


FIGURE 19.—Sections of folded Conestoga limestone in William Grothe Brick Co. clay pit southeast of York: A, Sketch of folds in the limestone showing sericitic clay derived from weathering of highly argillaceous layers; B, Detail of structure traced from photograph of a fold in the limestone, fold overturned to the northwest, cut by cleavage that dips southeastward and veined by quartz.

layers, and in places beds that contain abundant glassy quartz grains and weather to a porous, friable sandstone composed of rounded quartz grains. Because the limestone is closely folded, its thickness cannot be measured. Estimated to be more than 500 feet thick, the formation is probably much thicker where it is more fully exposed in the Lancaster and McCalls Ferry quadrangles.

The Conestoga limestone in the Hanover-York district is poorly exposed and no continuous section can be measured. In the York Valley east of York are many outcrops of thick-bedded granular limestone. Some of these beds contain quartz grains and coarse conglomerate and belong to the lower part of the formation. Thin-bedded blue limestone is more plentiful and represents the upper part of the formation. Thin black graphitic shale partings within the Conestoga limestone have been observed near the south edge of the valley south and east of York and in the adjacent Middletown quadrangle. The best exposures of the Conestoga limestone in the district are in clay pits of the brick plants in the southeastern part of York, where the residual clay soil has been stripped from the limestone over large areas. In the Wm. H. Grothe Brick Co.'s pit, 1 mile west of Plank Road, the rock is largely thin-bedded platy blue micaceous limestone with some thicker granular, crystalline limestone beds as much as 3 inches thick. The rock contains many wavy micaceous argillaceous partings and beds as much as 20 feet thick composed of calcareous mica schist which weathers to micaceous sandy clay. These beds are typical of the upper part of the formation. The beds are closely folded and the folds are overturned to the northwest so that all the strata dip southeast. The slaty cleavage is transverse to the bedding and dips 80° SE. The folds were so tightly compressed that the material on the limbs was squeezed out, so that the beds on the limbs are thinned and those on the arches are thickened. (See fig. 19, and pl. 7, *B* and *C*.)

An abandoned clay pit half a mile to the northwest and within the built-up part of the city exposes thick beds of gray granular crystalline limestone containing scattered glassy quartz grains, thicker beds of conglomerate composed of granular limestone pebbles in a fine conglomeratic matrix, and interbedded thin layers of blue micaceous limestone. The beds are folded and dip 25° to 60° SE., and the well-developed slaty cleavage dips 40° SE. The thick granular and conglomeratic limestones are typical of the lower part of the formation. Similar conglomerates and interbedded thin blue limestones crop out in the southern part of the valley east of Spring Plains. At the old Stoner quarry north of Stoner Station, in the Middletown quadrangle, the following section of the lower beds was observed:

Section of lower part of Conestoga limestone at Stoner quarry north of Stoner Station

	Feet
Thick dark granular limestone and fine conglomerate	35±
Thin-bedded dark limestone containing much pyrite	2
Coarse conglomerate of white and dark granular marble and flat, angular dark slabby limestone pebbles in dark argillaceous fine conglomerate matrix; merges into dark argillaceous limestone	15
Thin-bedded dark argillaceous, micaceous limestone with shaly partings and pyrite cubes	3
Massive conglomerate composed of light-colored limestone pebbles as much as 2 feet in size, in dark finely conglomeratic matrix	20
	75±

The lower conglomeratic beds are exposed in the south quarry north of Wrightsville, at Susquehanna River, and the section of the exposed beds is given under Kinzers formation, on page 20, and in figure 8.

A fairly good exposure of the basal part of the Conestoga may be seen along a new road cut on State Highway 274, from Kline School in the northeastern corner of the York quadrangle to the Susquehanna River in the McCalls Ferry quadrangle; but, because of folding and concealed contacts, thicknesses of beds can be only roughly estimated.

Road section of basal part of Conestoga limestone east of Kline School

	Feet
Conestoga limestone:	
Blue to gray limestone conglomerate; somewhat folded; beds 10 to 20 feet thick; composed of gray crystalline even-grained limestone pebbles in dark crystalline limestone matrix inclosing rounded glassy quartz grains	40±
Concealed (old roadway)	40±
Thin dense black argillite bed	5±
Black limestone conglomerate composed of granular crystalline limestone pebbles in dark limestone and black slate matrix (exposed in a local anticline beneath the argillite)	20±
Kinzers formation (lower member):	
Black graphitic slate (upper part contorted)	20±
Black slate	10±
Impure dolomite with slaty partings (may be reworked Vintage with interbedded shale; poorly exposed)	20±
	50±

Vintage dolomite: massive gray granular dolomite.

In the belt of Conestoga limestone southwest of York, in the Hanover quadrangle, outcrops are meager as the limestone has weathered largely to a deep soil containing abundant small irregular residual fragments of vein quartz. The exposed rock is largely dark-blue impure limestone with some black slate and limestone conglomerate. In the larger flat valley around Hanover outcrops of the formation are few; and in most places the only indications of the formation are the presence of small thin residual fragments of black shale, blotched with white from weathering, and irregular pieces of residual quartz in the soil. The Hershey sand quarry in the northern part of Hanover exposes thick beds of granular quartzose limestone and limestone conglomerate with a matrix that is composed largely of round glassy quartz grains. The conglomerate weathers to sand. The pebbles of the conglomerate are elongated parallel to the cleavage, which is transverse to the bedding. (See pl. 8, *A* and *B*.) These beds are similar to those near the base of the formation which are quarried at Midway and westward in the Gettysburg quadrangle, where the following section was measured:

Sections of quartzose limestone of the Conestoga at school in North Midway, 2 miles west of Hanover

	Feet
Blue thin-bedded slaty argillaceous limestone containing scattered pebbles of sandy white marble; veined with calcite	5±
Sandy limestone; weathers to porous rust-stained sandstone	10
Limestone conglomerate containing pebbles of sandy limestone	5
Banded impure blue limestone	3
Dark limestone	5±
White marble containing dark limestone pebbles; long pebbles of sandy limestone at base; local unconformity	6±
Thick beds of sandy limestone containing many rounded glassy quartz grains; weathers to crumbly, porous, rust-stain sandstone (quarried for building sand)	20±
Thin-bedded impure blue limestone (poorly exposed; thickness not determinable).	
	54±

In the Jefferson syncline where outcrops are few, narrow bands of limestone that have been mapped as Conestoga overlie Antietam quartzite. Small masses of Vintage dolomite occur at the quartzite contact in places. In the lowland scattered exposures of black clay, probably residue of graphitic limestone, and residual fragments of thin-bedded porous sandstone and

A. CONESTOGA LIMESTONE SHOWING CHARACTERISTIC THIN BEDS WITH ARGILLACEOUS AND CARBONACEOUS PARTINGS.

Thicker lenticular bed is dolomite. Quarry in eastern part of Columbia, Lancaster quadrangle.

B. CLOSELY FOLDED THIN-BEDDED ARGILLACEOUS BANDED CONESTOGA LIMESTONE.

In clay pit of William Grothe Brick Co., southeast of York. Folds overturned to the northwest; layers offset by cleavage dipping 50° SE.

C. DETAIL OF STRUCTURE AND CLEAVAGE IN THIN-BEDDED ARGILLACEOUS CONESTOGA LIMESTONE SHOWN IN *B.*

A SANDY LIMESTONE AND OVERLYING BED OF SHEARED LIMESTONE CONGLOMERATE OF THE CONESTOGA, HERSHEY SAND CO. PIT, HANOVER.

Cleavage is steeper than bedding and dips 60° SE.

B. BEDDING SURFACE OF CONGLOMERATE IN SAME QUARRY.

Shows irregular angular blocks of limestone in sandy limestone matrix.

C. UNCONFORMABLE CONTACT OF CONESTOGA LIMESTONE ON LOWER CAMBRIAN DOLOMITE, OLD QUARRY 2 MILES NORTHEAST OF LANCASTER.

Large angular blocks of white marble in basal beds of the Conestoga.

D. FERRUGINOUS LIMESTONE CONGLOMERATE OF THE CONESTOGA LIMESTONE FILLING CREVICES IN LOWER CAMBRIAN DOLOMITE, NEAR CONESTOGA CREEK, 2 MILES NORTHEAST OF LANCASTER.

quartz represent the Conestoga. Masses of ferruginous chert and brown iron ore lie along the fault on the south side of the valley.

At Penn Grove, 4 miles east of Hanover, is a large limestone cove surrounded by the Harpers phyllite of the Stoner overthrust block. The only evidence that the limestone in the southern part of this cove is Conestoga is the presence of a few fragments of blue limestone partly altered to iron ore, dark ferruginous chert, and much residual quartz. The Conestoga limestone here overlies black slate of the Kinzers formation.

UNCONFORMITY AT BASE

The irregular distribution and discordance with underlying formations in the region clearly indicate that the Conestoga limestone is unconformable on these formations. Because of the general lack of clear contacts, however, the precise nature of the overlap is difficult to determine. In general, the dip of the Conestoga limestone beds accords with the dip of the underlying or adjacent formation; but in a few quarries the relations are clearly discordant. In the old quarry north of the Lancaster water works (pl. 8, *C*), a conglomerate, composed of large blocks of white marble in a darker finely conglomeratic limestone matrix, at the base of the Conestoga, rests with marked unconformity on the Lower Cambrian dolomite. South of this quarry, deep channels and narrow crevices, with nearly vertical walls and as much as 20 feet deep, in the underlying limestone are filled with this limestone conglomerate. (See pl. 8, *D*.)

West of the quarry in which the unconformity is exposed is another quarry operated by C. D. Stoner of Columbia.[37] The present opening on the north side of the quarry exposes a gentle anticline in thick-bedded ribbed blue limestone and thinner argillaceous beds. When this quarry was visited in connection with the preparation of the report on the Lancaster quadrangle, the writers believed that the ribbed and rhythmically banded earthy limestones belonged in the Conestoga formation because east of York similar beds at the same stratigraphic position contain fossils which were then considered to be of probable Chazyan age. As the brachiopod is now known to be *Nisusia festinata* (Billings),[38] the banded blue limestone in which it occurs is of Lower Cambrian age and undoubtedly part of the underlying Kinzers formation. In the south side of the quarry, the southward-dipping blue crystalline limestone and limestone conglomerate of the Conestoga overlie the Kinzers formation in an unconformable or fault relation. North of Lancaster westward to Columbia in the Lancaster quadrangle, and in the Middletown quadrangle west of Susquehanna River, the writers and others have found fossils of Lower Cambrian age in similar beds at this stratigraphic position. Therefore, the mapping of the Kinzers formation and the northern boundary of the Conestoga limestone in those areas has been revised. (See fig. 24.) Likewise, argillaceous and sandy limestones, originally mapped as Conestoga in the Gettysburg area west of the Hanover quadrangle,[39] are beds in the Kinzers formation. The revised geology of the adjacent portion of the Gettysburg quadrangle is given in figure 20.

AGE AND CORRELATION

The Conestoga limestone is unconformable on the Ledger dolomite and older rocks of the region and in places overlaps the Antietam quartzite of Lower Cambrian age. These facts indicate that the Conestoga limestone was deposited after a period of uplift and erosion and that it is therefore considerably younger than the underlying formations. In the Hanover-York-Lancaster area, the Ledger dolomite of Lower Cambrian age is the youngest rock overlain by the Conestoga limestone. In Chester Valley near Coatesville, limestones continuous with and tentatively correlated with the Conestoga limestone overlie Elbrook limestone, and west of Coatesville these rocks progressively overlap the older formations down to the Antietam.[40]

No fossils have been found in the Conestoga limestone in this area. As stated previously, fossils collected by the writers in the quarry of the York Valley Lime & Stone Co., 5 miles east of York, were originally reported [41] to be of Chazyan age. They are now known to be of Lower Cambrian age and the beds in which they occur are part of the Kinzers formation. At Henderson Station in the eastern part of Chester Valley south of Norristown, limestones tentatively correlated with the Conestoga have yielded the only determinable fossils that may belong to this formation. E. O. Ulrich and A. F. Foerste have assigned Beekmantown age to these cephalopods and gastropods.[42] The limestones in Chester Valley are therefore of Lower Ordovician age. The age of the Conestoga limestone in the type locality in Lancaster Valley and westward in the Hanover-York district can be ascertained only if fossils are obtained in that region. Consequently, at present the formation is classed as of probable Ordovician age.

[37] Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Lancaster quadrangle, Pa.: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas No. 168, p. 75, 1930.

[38] Stose, G. W., and Jonas, A. I., Age reclassification of the Frederick Valley (Maryland) limestones: Bull. Geol. Soc. Amer., vol. 27, p. 1671, 1936.

[39] Stose, G. W., U. S. Geol. Survey Geol. Atlas (no. 225), Fairfield-Gettysburg folio, Gettysburg geologic map, 1929.

[40] Stose, G. W., U. S. Geol. Survey Geol. Atlas (no. 223), Coatesville-West Chester folio, Coatesville geologic map, 1932.

[41] Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pa.: U. S. Geol. Survey Bull. 840, p. 35, 1933.

[42] Jonas, A. I., and Stose, G. W., Age reclassification of the Frederick Valley (Maryland) limestone: Geol. Soc. America Bull., vol. 47, pp. 1670–1673, 1936.

In the southwestern end of the Hanover Valley at the Pennsylvania State line the Conestoga limestone is in strike with the limestones of the Frederick Valley, Md., 15 miles to the southwest. The intervening area is covered by Triassic rocks. The limestones of Frederick Valley comprise the Frederick limestone with fossils of Upper Cambrian age and the overlying Grove limestone which contains Lower Ordovician fossils. The Frederick limestone is a thin-bedded argillaceous limestone with limestone conglomerate beds, and the Grove limestone is purer limestone with dolomitic beds containing glassy quartz grains near the base. The Conestoga is more closely folded and more metamorphosed than the limestones of Frederick Valley, but it bears a strong lithologic resemblance to them and may be equivalent in part to both the Frederick and Grove limestones, and possibly in part, Upper Cambrian in age.

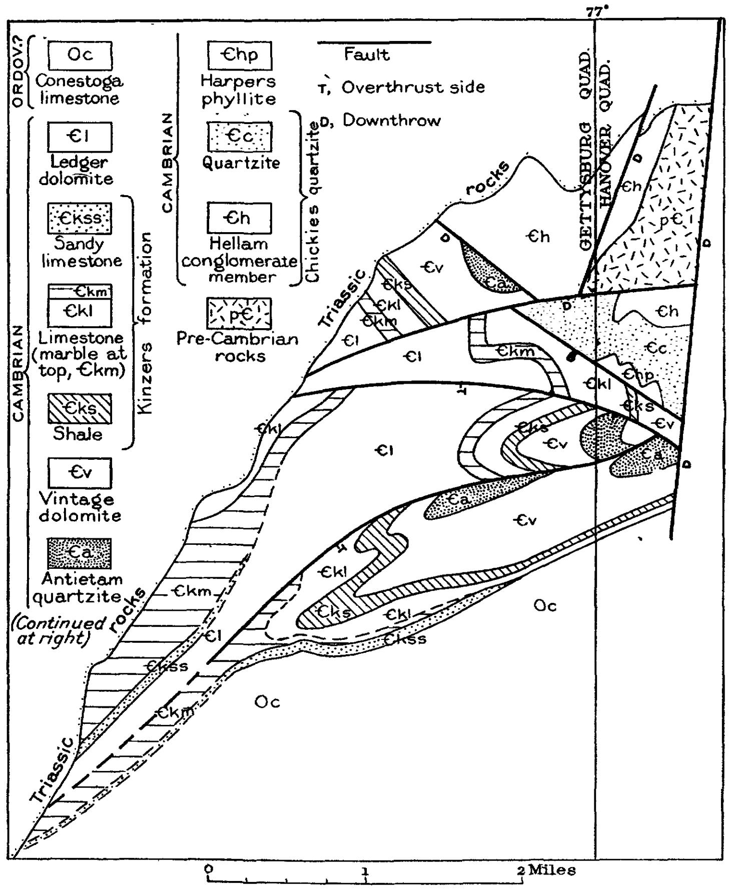


Figure 20.—Geologic map of eastern part of the Gettysburg quadrangle, revised to accord with present mapping in the Hanover quadrangle. Sandy limestone, previously mapped as part of Conestoga limestone, and white marble formerly mapped as Ledger dolomite, are now regarded as Kinzers.

ROCKS OF THE MARTIC OVERTHRUST BLOCK

The Martic overthrust block lies southeast of the known Paleozoic rocks of the East Prospect and Jefferson synclines and the Holtz anticline. The rocks of the Martic overthrust block are crystalline schists, largely derived from argillaceous and arenaceous sedimentary rocks, and include mica schist, quartzite, the Wakefield marble, and associated volcanic flows and metomorphosed tuffs.

The albite-chlorite schist facies of the Wissahickon formation occupies the southeastern part of the block. In the northwestern part of the albite-chlorite schist area, a belt containing infolded metabasalt extends from a point southwest of Brownton southwestward across the area and passes into Maryland. Northwest of the Wissahickon formation and the metabasalt belt are fine-grained albite-chlorite schist and chloritoid schist, here called the Marburg schist. The Marburg schist contains infolds of associated quartzites in the Yoe and Wentz synclines.

WAKEFIELD MARBLE

DISTRIBUTION

The Wakefield marble is apparently the oldest formation in the region and underlies the albite-chlorite schist facies of the Wissahickon formation. In a narrow valley in the southern part of the district, clay derived from weathered marble extends southwestward from Hokes post office to Blackrock at the Maryland State line. South of Blackrock and at a point 1 mile east of Lineboro, other narrow valleys in Maryland contain beds of marble, which extend into Pennsylvania. The marble is poorly exposed in Pennsylvania, but southwestward in Maryland it crops out across Carroll and Frederick Counties,[43] where it is associated with volcanic rocks.

In the valley east of Zumbrum school 2 miles south of Marburg, white impure marble is exposed in an old quarry east of the road along the valley. The marble is surrounded by the Marburg schist and is exposed along a fault that offsets the quartzite associated with the schist. Twelve miles to the northeast in a valley, which extends from a point three-quarters of a mile east of Loganville northeastward to East Branch of Codorus Creek, blue crystalline limestone is in strike with white marble. The limestone crops out in several old quarries on the northwest side of the valley. At both ends of the area are limonite pits, now abandoned and filled with water. The limestone is surrounded by Marburg schist; both formations are closely folded; and at the southwestern end, a narrow infold of the schist extends into the limestone.

CHARACTER AND THICKNESS

No fresh exposures of the Wakefield marble have been found in the district. Everywhere the rock is weathered to a blue clay. In Carroll County, Md., the marble of this belt is a crystalline bluish-gray to white marble composed of coarsely crystalline calcite with some finer grains of calcite, quartz, and muscovite. Under the microscope, the calcite is seen to contain inclusions of quartz and feldspar; and impure layers of the marble contain muscovite, biotite, and chlorite. The accessory minerals are leucoxene, pyrite, zircon, and tourmaline. Where the metabasalt is absent between the marble and the albite-chlorite schist facies of the Wissahickon formation, the marble grades upward into the Wissahickon schist through a calcareous schist which contains bands of muscovite, chlorite, albite, quartz, and calcite. Its thickness in southern Pennsylvania and the adjacent part of Maryland can not be measured but is estimated to be 100 feet.

NAME AND CORRELATION

The Wakefield marble takes its name[44] from Wakefield Valley in western Carroll County, Md. It has been correlated with the Cockeysville marble of Baltimore County, Md. The Cockeysville marble is coarser grained and is overlain by the oligoclase-mica schist facies of the Wissahickon formation, but has no associated volcanic rocks. The correlation is not well established; therefore, the name Wakefield is used here.

In the valley east of Loganville blue thin-bedded crystalline limestone contains argillaceous bands which form slaty muscovite partings. This rock resembles the Silver Run limestone,[45] of Maryland, which in places seems to grade into the Wakefield marble and may be equivalent to it. In this report the blue limestone is included with the Wakefield marble.

METABASALT

The metabasalt occurs in narrow areas surrounded by the albite-chlorite schist facies of the Wissahickon formation from points near Brownton and Brogueville Station southwestward to the Maryland line. The long narrow areas in the northeast part of the belt widen to 6 miles in the vicinity of Glen Rock. The best exposures are several narrow bands in the valley of Codorus Creek and in road and railroad cuts from Glen Rock southeastward to Shrewsbury Station, but fresh exposures are few. Because it is less resistant to erosion than the inclosing Wissahickon formation, the metabasalt occupies narrow longitudinal valleys between ridges of albite-chlorite schist and chloritoid schist. The metabasalt weathers readily to rusty porous blocks ("worm-eaten rock") which the farmers use extensively in making stone walls.

In the district the metabasalt is a green schistose rock composed of albite, uralitic hornblende, and epidote. It contains veins of quartz and epidote, and, in the more massive outcrops, has amygdules of quartz and epidote. Thin sections under the microscope show albite, zoisite, and epidote, which are secondary to a lime-soda feldspar, and uralite and chlorite derived from pyroxene. The metabasalt is closely folded; and the crests of the folds are sheared out in large part, forming foliation layers which generally dip 45° NW. This foliation[46] is cut by a transverse nearly vertical cleavage. Metabasalt is infolded with the overlying albite-chlorite schist of the Wissahickon, which it resembles in weathered outcrops, and with chloritoid schist, which may be of tuffaceous origin but which has been mapped with the albite-chlorite schist facies of the Wissahickon formation.

WISSAHICKON FORMATION

NAME AND DISTRIBUTION

The Wissahickon formation was named from Wissahickon Creek near Philadelphia, where the rock is an oligoclase-biotite-muscovite schist. This schist lies on the southeast side of the Peters Creek quartzite. On the northwest side of this quartzite there is a belt of albite-

[43] Jonas, A. I., and Stose, G. W., Geologic map of Frederick County and adjacent parts of Washington and Carroll Counties, Md., Maryland Geological Survey, 1938.

[44] Jonas, A. I., and Stose, G. W., New formation names used on the geological map of Frederick County, Maryland, Washington Acad. Sci. Jour., vol. 28, p. 346, 1938.

[45] Jonas, A. I., and Stose, G. W., New formation names used on the geologic map of Frederick County, Md.: Wash. Acad. Sci., vol. 28, p. 346, 1938.

[46] For definitions of these terms, as used in this report, see p. 41, under Wissahickon formation.

chlorite-muscovite schist regarded as a different metamorphic facies of the Wissahickon formation. This schist has been called the albite-chlorite schist facies of the Wissahickon formation. This albite-chlorite schist facies occupies most of the southeastern part of the Hanover-York district. The northwest boundary of the exposures extends from a point about a mile north of Rockey southwestward through Springvale, Graydon, and Glenville. The Wissahickon formation lies southeast of the Marburg schist and contains infolds of metabasalt. The best outcrops are in valleys that cut across the strike of the formation, namely, those of North and South Branches of Muddy Creek and Deer Creek, which flow southeast, and those of East and South Branches of Codorus Creek, which flow northwest across the Hanover quadrangle.

The belt of albite-chlorite schist is the southwestern continuation of the albite-chlorite schist belt of the McCalls Ferry quadrangle.[47] From the York-Hanover district it extends southwest into the albite-chlorite Wissahickon formation occurring in Baltimore County, Md.[48]

CHARACTER

The Wissahickon formation in the Hanover-York district is a coarse-grained sparkling grayish-blue or green schist, whose dominant minerals are albite, chlorite, muscovite, and quartz. It is interlayered with quartzite and muscovite and chloritoid schists. In general the schists are of coarse grain in the southeast part of the area and become finer grained to the northwest. The metamorphism is that of the "green-schist facies."

The schists in the Wissahickon formation may be divided into a type containing albite and a type containing chloritoid and lacking albite. The size of the albite grains differs greatly in the albitic schist, which may be separated into two varieties. One is a muscovite-chlorite-quartz schist characterized by small albite grains. It is garnetiferous in part of the area, and has a microscopic layering of fine opaque dust, largely ilmenite and iron-oxide particles, which forms a stream line of inclusions in the albite grains. This schist is characterized by rusty weathering. The second variety has coarse albite metacrysts and contains also muscovite, chlorite, quartz, and, in part of the area, garnet. Epidote is usually present, and the inclusions in the albite grains comprise garnet, muscovite, epidote, ilmenite, and iron oxide. The chloritoid schist contains chlorite, muscovite, and quartz.

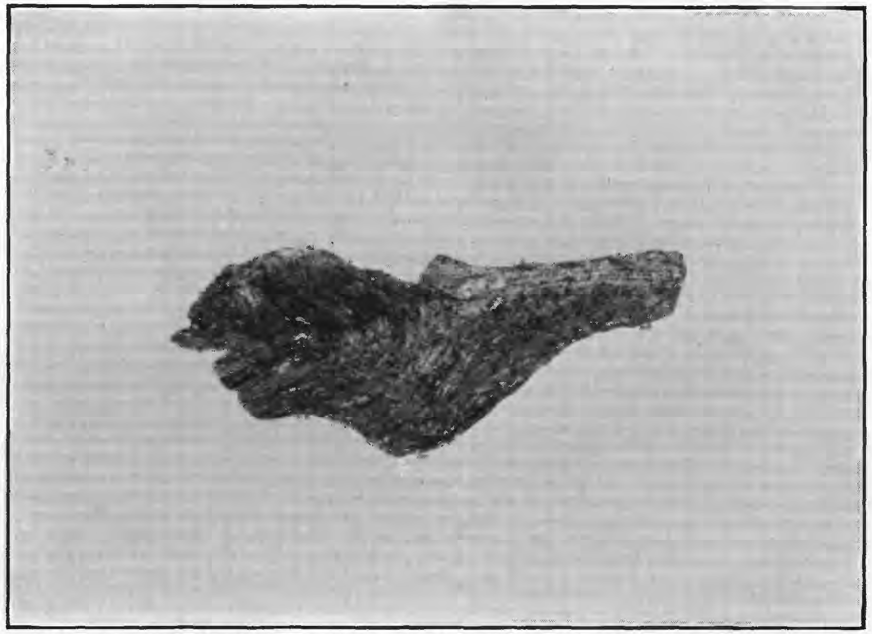
Schistose quartzite containing blue quartz grains is infolded with these schists. In part the quartzite is graphitic. The schists also contain layers and lenses of quartz which are parallel to the layers of the schist and folded with them. Because of close folding, various kinds of schist and quartzite of the Wissahickon formation may occur in the same outcrop; consequently, the varieties of schists are not indicated on the map. Quartzite is mapped south of Felton in the valley of Muddy Creek where the rock is infolded with albite-chlorite schist. Similar quartzite exposures have been traced from a point near Springvale southwestward, passing north of Glen Rock; others lie northwest of Sticks. Quartzite has been mapped also on the northwest side of two metabasalt belts between Seitzland and Shrewsbury Station. The quartzite is fine-grained, with a white or green color. It has muscovite partings. Some layers contain stretched blue or milky quartz pebbles which, in the area north of Glen Rock Valley, are as much as two inches long. The quartzite is infolded with green quartzose chlorite schist and lustrous blue chloritoid schist with crumpled quartzose layers. North of the wide area of metabasalt at Glen Rock, the quartzite containing blue quartz layers is infolded with chlorite schist, albite-chlorite schist, and metabasalt. The quartzite north of Rockey and in strike with outcrops at Springvale has a white sugary texture, contains muscovite partings, and is closely folded. It resembles the quartzite that occurs northeast of Sticks and south of Glenville and that extends southwestward toward Blackrock. As these quartzites are exposed only in stream valleys, contact boundaries are shown by dashed lines.

STRUCTURE

Before describing the schists of the Wissahickon formation in microscopic detail, a general account of the structure of the area is essential. The axis of the Tucquan anticline, which is in the albite-chlorite schist facies, crosses the southeast corner of the York quadrangle and extends to the edge of the district in a line nearly parallel to South Branch of Muddy Creek. This fold is the southwestward continuation of the Mine Ridge anticline, in which pre-Cambrian gneisses and overlying lower Paleozoic sedimentary rocks are exposed in the Quarryville and McCalls Ferry quadrangles. The Paleozoic rocks dip southwestward from the nose of Mine Ridge anticline; and the youngest of the series—The Conestoga limestone—passes southwestward under the albite-chlorite schist of the Wissahickon formation, which is bowed up into the Tucquan anticline.

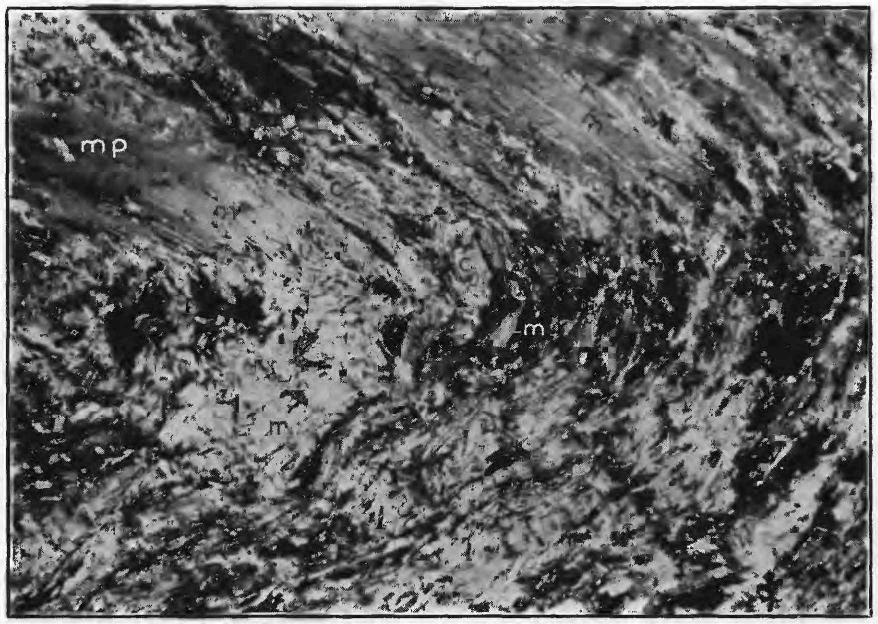
The Wissahickon formation for the most part is made up of thinly laminated alternate micaceous and quartzose layers. The quartzose layers are generally discontinuous and form elongated lenticles in a micaceous envelope. The formation also contains recumbent folds, best preserved in the quartzite layers. South of Felton the amplitudes of these folds is 4 feet. In the mica schists recumbent folds of smaller dimension have been observed northwest of the crest of the Tucquan anticline for a distance of 8 miles, and also southeast of the anti-

[47] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district, Pennsylvania: U. S. Geol. Survey Bull. 799, p. 35, 1929.
[48] Knopf, E. B., and Jonas, A. I., Baltimore County, Maryland Geological Survey, pp. 167–174, 1929.



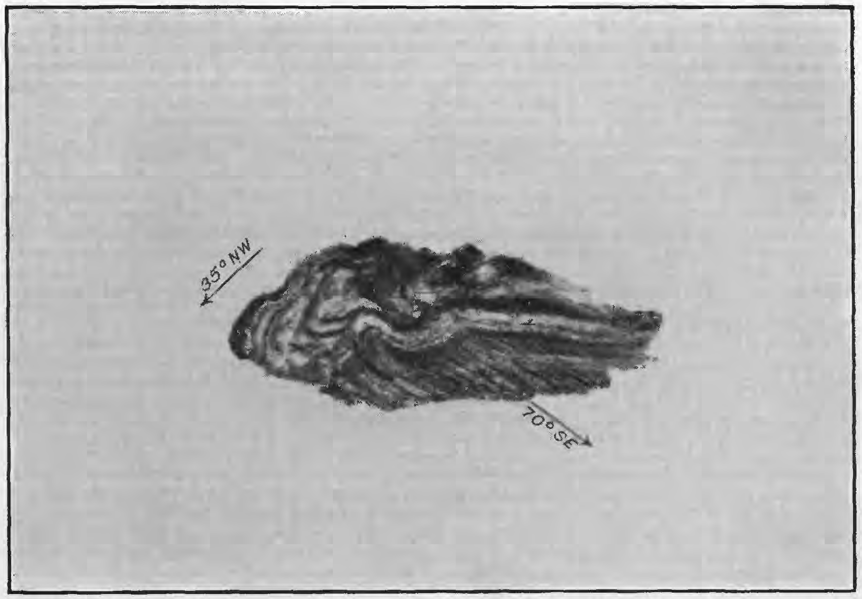
A. POLISHED SURFACE OF RECUMBENT FOLD IN CHLORITE-MUSCOVITE-QUARTZ SCHIST TUCQUAN ANTICLINE.

Looking S. 65° W. Axial plane horizontal; cleavage dips 60° NW. Natural size.



B. THIN SECTION OF SPECIMEN SHOWN IN *A*, SIMILARLY ORIENTED.

Muscovite with layers of fine dust (m); chlorite (c); muscovite porphyroblast (mp) lying across earlier-formed muscovite. × 8½.

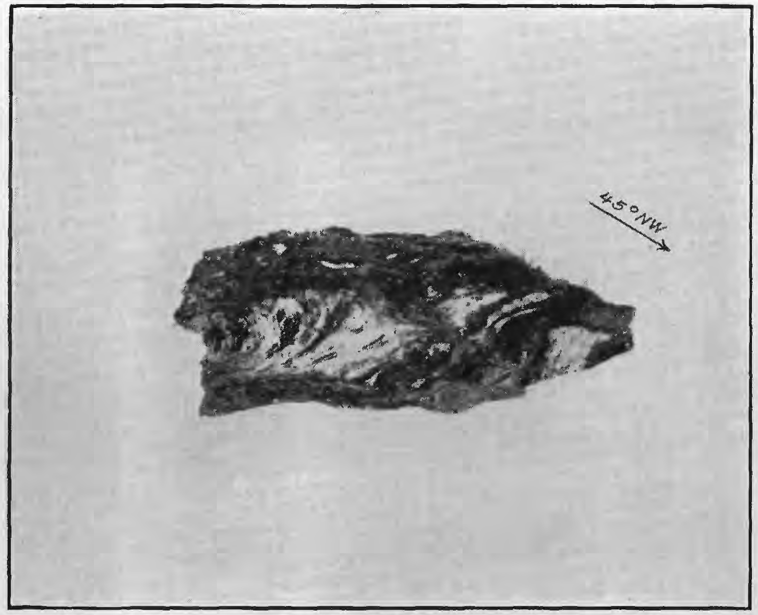


C. POLISHED SURFACE OF RECUMBENT FOLD IN CHLORITOID SCHIST, 6 MILES NORTHWEST OF TUCQUAN ANTICLINE.

Looking N. 65° E. General foliation dips 35° NW.; transverse cleavage dips 70° SE. Natural size.

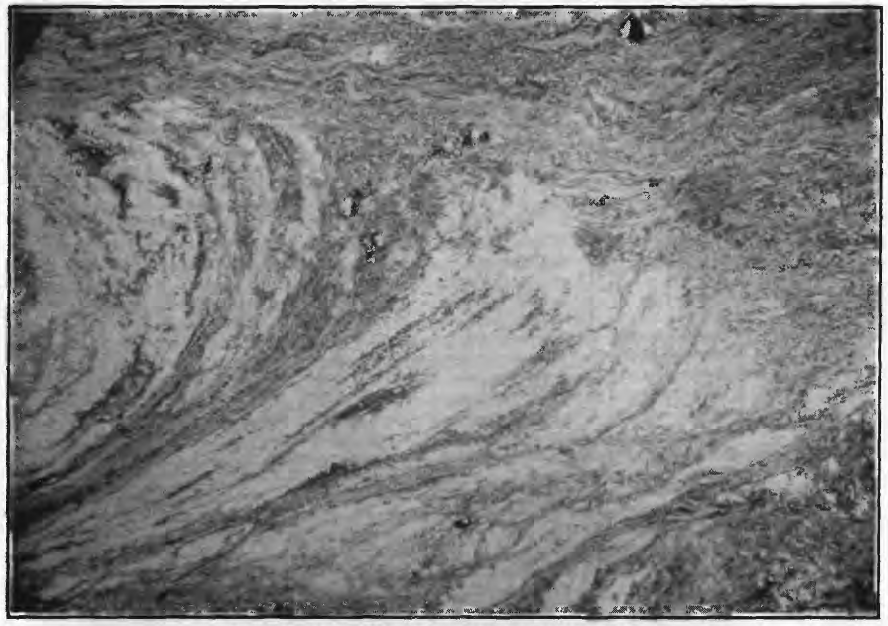
D. THIN SECTION OF SPECIMEN SHOWN IN *C*.

Muscovite, chlorite, and chloritoid blades (m); quartzite layers (q). × 6.



A. POLISHED SURFACE OF RECUMBENT FOLD IN ALBITE-CHLORITE-MUSCOVITE-QUARTZ SCHIST, 7 MILES NORTHWEST OF TUCQUAN ANTICLINE.

Looking S. 35° W. General foliation dips 45° NW. Limbs partly sheared out. Natural size.

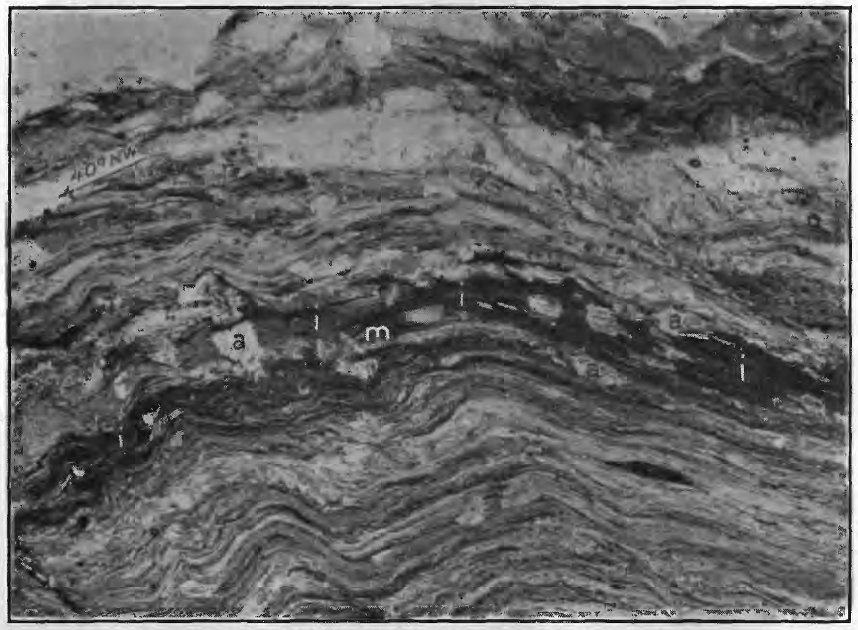


B. THIN SECTION OF SPECIMEN SHOWN IN *A.*

Recumbent fold in part transformed to foliation. × 6.

C. MUSCOVITE-CHLORITE-QUARTZ SCHIST FROM MUDDY CREEK FORKS, 1 MILE SOUTHWEST OF HIGH ROCK, McCALLS FERRY QUADRANGLE. × 6.

Contains ilmenite (black specks). Cleavage dipping 70° SE. is prominent in micaceous layers.



D. ALBITE-MUSCOVITE-CHLORITE SCHIST FROM FENMORE.

Shows contorted muscovite and chlorite containing layers of ilmenite and iron oxide dust (i), which pass through the albite grains (a), and muscovite porphyroblast (m) diagonal to layering. × 8½.

cline in the McCalls Ferry quadrangle, for a distance of 5 miles.

Even where folds are invisible to the unaided eye, thin sections generally show closely appressed folds whose axial planes are parallel to the foliation of the schist. In such rocks the larger folds have been sheared out along the crests, and the microscopic crumples are the only remnants of the recumbent structure. Foliation, therefore, is here used to denote a mechanical differentiation of original material into more or less irregular layers, the layering being the result of slipping in closely appressed and drawn out folds so that the crests of the individual folds are largely destroyed. Such a foliation lying parallel to transposed *S*-planes has been called by E. B. Knopf[49] "transposition cleavage," in contrast to "slaty cleavage" or transverse cleavage which cuts across the *S*-planes.

At the crest of the Tucquan anticline, the foliation is horizontal or gently rolling. The axial planes of the recumbent folds, which are parallel to the foliation, are also horizontal at the crest of the arch; and both the axial planes and the foliation dip northwestward on the northwest limb of the arch and southeastward on the southeast limb. The dip of the foliation layers and of the axial planes of the folds gradually steepens in both directions away from the crest of the Tucquan arch. At Brownton, 7 miles northwest of the crest of the anticline, the foliation dips 55° NW., is minutely folded and crumpled, and is broken by steeply-dipping superimposed cleavage transverse to the micaceous layers and more prominent in them.

MICROSCOPIC DESCRIPTION

Polished specimens of schist with recumbent folds, in some of which the crests are in part or entirely sheared out into foliation layers, together with thin sections cut from these specimens, are given in plates 9 to 11. They illustrate the development of transposition cleavage or foliation formed by the shearing out of the crests of the recumbent folds. All the polished specimens and thin sections figured in this report were cut at right angles to the fold axes, or lineation of the Tucquan anticline. In this area the fold axes are horizontal or have a maximum pitch of 20°–40° SW. As the lineation on the cleavage planes is parallel to the fold axes, the sections are cut at right angles to the lineation where fold axes are not evident. The polished specimens are marked to show their orientation in the field outcrops, and the thin sections exhibit on a minute scale the megascopic structure seen in the outcrops.

Plate 9, *A* shows a recumbent fold in a specimen of mica schist collected north of High Rock and 2 miles southeast of Laurel on North Branch of Muddy Creek on the crest of the Tucquan anticline where the axis of the fold and the foliation are horizontal. The thin section (pl. 9, *B*) shows muscovite and chlorite, which are flexed on the outside of the fold and include layers of a fine, opaque dust, probably ilmenite and oxide of iron.[50] The coarser-grained ilmenite, titanite, and micaceous minerals are bent on the crest. On the concave side of the arch, the micas are mechanically undistorted; and their crystallization outlasted the flexing of the fold. Hence, in respect to the mica crystallization, the folding is paracrystalline. Coarse blades of muscovite and chlorite, formed late in the process of crystallization, lie at angles to the direction of the earlier-formed micas and are arranged in two intersecting groups of parallel lines.

A schist of similar composition (pl. 10, *C*) from Muddy Creek Forks, one mile southwest of High Rock in the McCalls Ferry quadrangle, shows folded quartz lenses and well-developed later cleavage. This rock contains also coarse crystals and fine grains of ilmenite. A recumbent fold in a schist of different composition is shown in plate 9, *C*. The specimen was collected 6 miles northwest of the Tucquan anticline, 2 miles southwest of Felton, where the foliation dips 35° NW. The fold shows crumpling and displacement along slip planes, which dip steeply southeast. The schist (pl. 9, *D*) exhibits paracrystalline folding of muscovite, chlorite, and chloritoid, which in part were formed late in the folding. This chloritoid schist is infolded with albite-chlorite schist.

Plate 10, *A* and *B* illustrates a bluish-gray muscovite-chlorite schist collected a short distance to the southwest of the place where the specimen shown on plate 9, *C* and *D* was obtained. The recumbent folds are partly sheared out and are recognizable only in the quartzose layers. The specimen shows paracrystalline folding and late coarse unbent blades of chlorite and muscovite. Ilmenite, which is present as fine opaque dust and thin plates, has been folded. In both specimens (pls. 9, *C* and 10, *A*), the paracrystalline micaceous minerals of the schist are lustrous and not sparkling because the mica flakes were shearing out during folding.

In a fine-grained albite-chlorite-muscovite schist from Fenmore (see pl. 10, *D*), prominent layers are formed by muscovite and opaque dust of ilmenite and iron oxide. The albite porphyroblasts in the rock contain streamlines of the opaque dust and mica of the groundmass; and the centers, which contain the helicitic pattern, are surrounded by clear albite rims formed at a later time. This rock shows a crumpled, thin-layered foliation in which recumbent folding is discernible only in minute folds. The larger flexures were sheared out

[49] Knopf, E. B., Retrogressive metamorphism and phyllonitization: Am. Jour. Sci., 5th ser., vol. 2, pp. 16–18, 1931.

[50] The microscopic and chemical determination of the ilmenite and iron oxide, which occurs in the fine opaque dust, was made by J. J. Glass, J. J. Fahey and T. Stadnichenko.

along the crests, and the resultant foliation layers were folded later in the movement which slightly rotated the albite grains and developed a steep superimposed cleavage transverse to the foliation.

The thin section shown in plate 11, *A* is cut from a sparkling muscovite-chlorite schist collected 1 mile south of Springvale. Foliation planes dipping 50° NW. and a steeper intersecting cleavage are the only structures visible in the outcrop. The thin section shows lenses of folded muscovite and chlorite alternating with quartzose layers. This chlorite and muscovite is paracrystalline to the shearing out of folds. Coarse muscovite porphyroblasts of later generation are not bent by the cleavage that intersects the older muscovite. Large black rods of ilmenite are partly surrounded by borders of chlorite. The coarsely crystalline muscovite of the second generation spangles the rock and tends to obscure the presence of early deformed muscovite and chlorite.

The coarse-grained albite-chlorite schist (pl. 11, *B*) is made up of chlorite, muscovite, epidote, apatite, titanite, and ilmenite in layers between the more quartzose bands. The micaceous layers contain coarse, somewhat rounded albite metacrysts in which are streamlined inclusions of such minerals as garnet, epidote, muscovite, and ilmenite. Sedimentary grains of apatite are greatly crushed, and the ilmenite plates are bent. Folding of the schist was paracrystalline. The pattern of the inclusions in the albite metacrysts records an early folding. These inclusions are not in line with the mica and chlorite blades that lie parallel to the folded layers of the schist; hence the writer concludes that the albites were rotated somewhat during the folding, subsequent to their crystallization.

The graphitic quartzite (pl. 11, *C*) came from one of the quartzose layers in a graphitic schist, which is well exposed on the highway 1 mile south of Seitzland, where it is in contact with metabasalt. Recumbent folding is visible in the quartzose layers, which contain fine muscovite blades. The schistose layers, composed of fine-grained muscovite and graphite, are broken by transverse cleavage dipping 80° SE.

THICKNESS

The Wissahickon formation includes schists of varying composition, crystallinity, and degree of metamorphism. Their most prominent structural feature is the foliation resulting from closely packed recumbent folds in which the closures usually are sheared out and the limbs torn apart by slipping movements. If the layered structure in the recumbent folds was original bedding layers, the foliation developed by shearing out of the folds is also largely parallel to the original bedding. The layers, whether they were originally sedimentary beds or not, are completely transposed and inverted so that the present superposition of layers is in no sense a stratigraphic succession. During the rise of the Mine Ridge anticline, the foliation, formed as a result of the slipping movement that accompanied recumbent folding, has been folded into the Tucquan anticline and its minor folds. No estimate of thickness, therefore, can be made and no vertical section of the formation can be given. The metamorphism, origin, correlation, and age of the Wissahickon formation will be discussed after the description of the Marburg schist.

MARBURG SCHIST

NAME AND DISTRIBUTION

The Marburg schist[51] was named from Marburg, York County, Pa., a village 5 miles southeast of Hanover. The Marburg schist in a belt about 5 miles wide crosses the Hanover-York district along the northwestern border of the Martic overthrust block. The formation enters the area from the McCalls Ferry quadrangle where it is well exposed along Susquehanna River from a point south of Creswell Station to and beyond Star Rock. In the report on that area,[52] schists now mapped as Marburg were included with the albite-chlorite schist facies of the Wissahickon formation; and, because of their quartzose character, certain schists near Long Level, York County, and south of Creswell Station, Lancaster County, were mapped as Peters Creek quartzite. In the present consideration of the Hanover-York district the Marburg schist has been separated from the Wissahickon formation, which lies southeast, because it is finer grained and, in the southwestern part of the area, contains schistose rocks apparently derived from volcanic tuff. The line separating the two formations is dashed on the map because grain size and metamorphism decrease gradually from southeast to northwest. The associated quartzites in the upper part of the Marburg schist are exposed in the Yoe and Wentz synclines.

CHARACTER

The Marburg schist is chiefly bluish-gray to silvery-green fine-grained schist which contains either muscovite, chlorite, albite, and quartz, or muscovite, chlorite, chloritoid, and quartz. Northeast of the East Branch of Codorus Creek in the York quadrangle, the schist is coarser grained and sparkles with porphyroblasts of muscovite. Because the varieties of schist that constitute the Marburg schist are interfolded and, in general, are separable only by examination in thin section, they are not separated on the map. Beds of quartzite and conglomerate form the upper part of the formation.

In the sparkling muscovite schist of the northeastern part of the area (pl. 12, *A*) the felty crumpled layers of fine muscovite, chlorite, and albite and the quartzose

[51] Jonas, A. I., and Stose, G. W., New formation names used on the geologic map of Frederick County, Maryland. Washington Acad. Sci. Jour., vol. 28, pp. 346–347, 1938.

[52] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district, Pa.: U. S. Geol. Surv. Bull. 799, pp. 25–37, 1929.

bands are crossed by a well-developed cleavage, which dips 85° SE. Another specimen of Marburg schist (pl. 12, *B*) contains coarse ilmenite porphyroblasts and coarse blades of muscovite that lie in two intersecting groups of parallel flakes at angles of 45° to the cleavage. These muscovite porphyroblasts for the most part were not bent by the cleavage; and their crystallization, therefore, was later than the earlier generation of muscovite and chlorite forming the foliation layers and later than the shearing movement that formed the cleavage.

In the Hanover quadrangle the muscovite and chlorite porphyroblasts, where present, are fine-grained and are visible only through a hand lens. The folding is close, and the nearly vertical cleavage transverse to the foliation is the prominent structure.

Plate 13, *A* represents a thin section of Marburg schist from an outcrop 1 mile north of Marburg. The magnification (×9) is the same as that in plate 12, *B*, and the difference in grain size is well illustrated. The dark layers are made up of fine-grained closely crumpled muscovite and chlorite blades and bands of fine black dust. The transverse cleavage dips 80° SE.

Plate 13, *B* shows part of the same thin section at a higher magnification (×27). The area enlarged is indicated in plate 13, *A*. The cleavage is evident in the micaceous layers but does not cross the quartzose layer.

A fine-grained grayish-green schist from Marburg (pl. 12, *C*) shows "transposition cleavage" cut by a later transverse cleavage. This schist is distinguished from the variety in the area to the northeast by the absence of muscovite and chlorite porphyroblasts.

The chloritoid variety of the Marburg schist is fine-grained, dense, and grayish. Two specimens are shown in plate 14, *A* and *B*. The one (pl. 14, *A*) from Saubel Hill, north of Glenville, is composed of muscovite, quartz, and chloritoid, whose dark prisms are arranged in sheaves. The central band is part of a lens whose structure is discordant to the structure of the schist that surrounds it. The light areas are composed of quartz, muscovite, and scanty chloritoid. The lens represents probably a remnant of an imperfectly transposed folded structure. The other specimen (pl. 14, *B*) from Hoffacker Valley has a muscovite and quartz groundmass in which chloritoid porphyroblasts developed during a late stage of crystallization.

QUARTZITES ASSOCIATED WITH THE MARBURG SCHIST

DISTRIBUTION

Associated quartzites are closely infolded in synclines in the Marburg schist. The quartzites are interbedded with slate and schist and form the higher hills in the Yoe and Wentz synclines. Quartzites form the crests of the ridges whose altitudes range from 800 to 1,000 feet in the southern part of the district and also the ridges on which Dallastown and Red Lion are built. A conglomeratic facies of the quartzite forms Huntrick, Beecher, and Saubel Hills, which range in altitude from 900 to 1,000 feet.

The quartzites and slates in the Yoe syncline lie northeast of Inners Creek and Rye and are surrounded by the Marburg schist. From Red Lion northeastward small areas of the quartzite lie south of the main syncline. The quartzites in the Wentz syncline, named from a village in Maryland 1 mile south of West Manheim, extend from a point near Loganville southwestward to the Maryland State line, a distance of 12 miles. At its broadest point, north of Hokes post office, the syncline is 2½ miles wide. A narrow area of black slate half a mile south of Seven Valleys, one southwest of Kinneys School, and another south of Myers School, probably represent synclinal infolds of the slate that is interbedded with the basal part of the quartzite near Zumbrum School and also in the Yoe syncline. The slate has been quarried locally in the first two areas.

CHARACTER

The lower quartzites contain black slate interbedded with siliceous bands, overlain by a thin green, rusty-weathering quartzite and thicker white to green quartzite with blue quartz grains. The uppermost beds, exposed only in the Wentz syncline, are of green schistose, ferruginous quartz conglomerate composed of quartz and slate pebbles and containing muscovite partings.

In the Yoe syncline the quartzite layers are thin and in part are interbedded in black slate. Coarser layers show blue quartz grains. The quartzites are closely folded and the outcrops are poor, so that layers cannot be traced as continuous ledges.

In thin section under the microscope, the siliceous banded slate (see pl. 14, *C*) from half a mile southeast of Freysville is a chlorite-muscovite phyllite containing layers of fine quartz, scanty albite, and rounded zircon. Muscovite and chlorite are parallel to a younger slip cleavage, which has been produced by a folding and slipping of the older, probably sedimentary layers. The phyllite contains chlorite porphyroblasts with large centers of ilmenite and ilmenite rods that have been deformed in the folding. The constituents are paracrystalline in respect to the last folding, and the metamorphism is of low rank. The siliceous, banded slate containing blue quartz grains (see pl. 13, *C*), from Inners Creek southwest of Dallastown, is composed of fine-grained quartz, muscovite, and black dust. Besides the quartz grains, which are white in the photomicrograph, there are grainlike aggregates of minute angular quartz fragments in a fine-grained dark matrix. The dark rods are ilmenite. The aggregates of angular quartz suggest that the rock may be a tuff mixed with

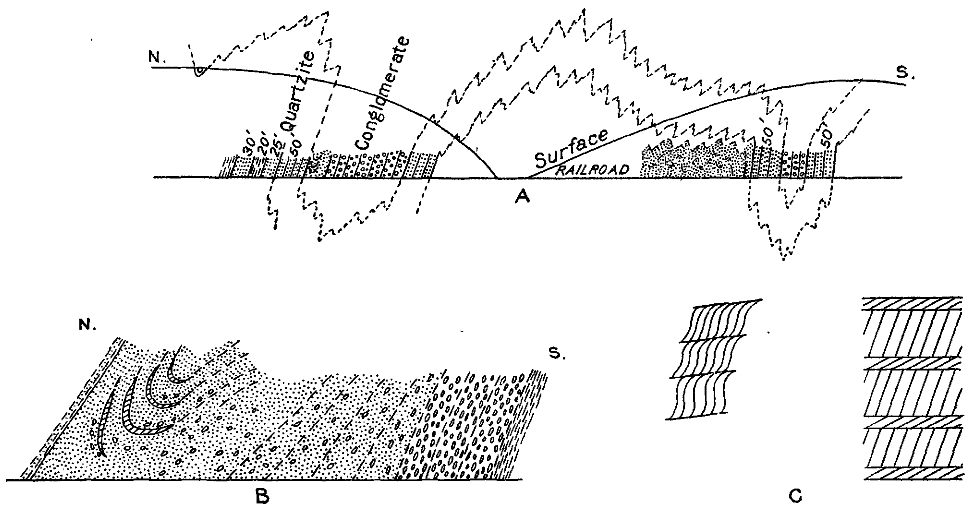


FIGURE 21.—Sections of Marburg schist and associated quartzites at Brodbeck: *A*, Sketch in railroad cut showing conglomerate beds in quartzite and the interpreted structure. *B*, Detail of structure in quartzite at north end of section. Bedding planes, emphasized by quartz stringers, are closely folded, and pebbles are elongated parallel to cleavage which dips steeply northward. *C*, Detail of cleavage observed in quartzose layers; steep dip in hard 6-inch layers; dip 30° N. to nearly horizontal in softer 2-inch beds.

land-derived quartz grains, but the evidence for tuffaceous origin is not conclusive.

The quartzites in the Wentz syncline are made up largely of dark-green ferruginous, sericitic quartzite interbedded with blue and green slate, some beds of which contain blue or milky quartz grains, muscovite, and chlorite. A coarse, pebbly green conglomerate in layers 2 to 4 feet thick is interbedded with the dark quartzite and blue slate. The schistose conglomerate contains flattened lenticular pebbles of quartz and sericite; and the blue and milky quartz pebbles are elongated, some being as much as 3 inches in length. Muscovite and chlorite are developed in the partings. The weathered conglomerate is porous and rusty brown, owing to the leaching out of its ferruginous cement.

Conglomerate and interbedded quartzite is well exposed on a curve of State Highway No. 616, 1 mile southwest of Larue. The beds are closely folded—the axes of the folds striking N. 40° E. and dipping 20° NE.—and are cut by transverse cleavage which dips 80° NW. Displacement to the southwest occurred along cross shear planes which dip 30° NE. The quartz conglomerate layers contain pebbles 1 inch long and are interbedded with rusty, green quartzite. The conglomerate crops out to the north and to the south of infolded green quartzite and phyllite. The thick beds of conglomerate are the most conspicuous part of the quartzite series and, in general, are the only beds traceable on the uplands. In stream valleys, as at Brodbeck, the pebbly quartzites may be seen in outcrop.

The best outcrops of the quartzites associated with Marburg schist in the Wentz syncline are along Codorus Creek north of Brodbeck, where for three-fourths of a mile the rock is almost continuously exposed. There, the thickness of the quartzite and interbedded conglomerate and phyllite is estimated to be about 150 feet. The section (see fig. 21) is complicated by folding, and the exposures are too shallow and discontinuous for the structure to be completely determined. The sequence has been interpreted as follows:

Composite section of the quartzites at the top of the Marburg schist at Brodbeck

	Feet
Sheared conglomerate containing pebbles 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 containing blue quartz grains with 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).	

METAMORPHISM OF THE SCHISTS OF THE MARTIC AND STONER OVERTHRUST BLOCKS

DESCRIPTION

The Wissahickon formation in Maryland, in the vicinity of the anticlines of Baltimore gneiss, is a coarse-grained schist of mesozone type. It contains biotite, muscovite, oligoclase, quartz, garnet, staurolite, and kyanite. Staurolite and garnet porphyroblasts, which grew during the folding, contain quartz inclusions that represent available silica in excess of that needed for the growing crystals. Coarse blades of biotite and muscovite formed during the last stage of crystallization.

Absence of deformation shows that their growth outlasted the folding, or, in other words, was post-tectonic.

The terms "epizone" and "mesozone" used by Grübenmann and Niggli [53] place an emphasis on the depth factor in metamorphism. Eskola [54] 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. He defines 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 in the oligoclase-mica schist facies of the Wissahickon formation in Maryland belong to the amphibolite schist facies and the rocks show little evidence of a change in metamorphic conditions throughout crystallization.

On the northwestern border of the belt of oligoclase-mica schist, evidence of a change in metamorphic intensity during folding is shown by retrogression of earlier-formed garnet and biotite to chlorite, and of staurolite to muscovite before metamorphism ceased. These diaphthoritic schists in the area southwest of Oxford, Pa., were described in the report of the McCalls Ferry-Quarryville district.[55] They extend southwestward into Maryland across Cecil and Harford Counties into Baltimore County, where they lie on the northwest side of the Phoenix anticline and southeast of the Peach Bottom syncline. It is evident in that area that the minerals of higher rank formed in earlier stages of crystallization were no longer stable under the conditions of temperature and pressure that obtained in the later stages.

In the Peach Bottom syncline lying northwest of this retrogressive zone, the Peters Creek quartzite also has undergone retrogression in the partial alteration of biotite to chlorite. The schist of the Peters Creek quartzite is finer grained than the oliogoclase-mica schist facies of the Wissahickon formation to the southeast; is a crystalline rock containing chlorite with biotite relics, epidote, quartz, and albite; and lies in the Peach Bottom syncline southeast of the albite-chlorite schist facies of the Wissahickon formation. This facies of the Wissahickon occupies a wide area in northern Baltimore County and extends northwestward into the Hanover-York district. In northern Baltimore County the albite-chlorite schist contains biotite and garnet, in part altered to chlorite. Biotite has not been found in the albite-chlorite schist in the Hanover-York area, but garnet persists as porphyroblasts and inclusions in the albite and has been observed northwestward to within a mile of Felton. A garnetiferous chlorite-muscovite-albite schist (see pl. 15, *A* and *B*), collected from the crest of the Tucquan anticline on the Susquehanna River, shows a crumpled foliation, formed by a shearing out of the earlier recumbent structure that is preserved elsewhere in the area. The garnet in this rock has not been altered to chlorite, although the other constituents of the rock—chlorite, muscovite, and albite—are of the "green schist" facies of metamorphism. At localities in the York quadrangle, the garnets have altered to chlorite on their surfaces and in cracks, thereby indicating a retrogression in metamorphism. Porphyroblasts of magnetite and tourmaline occur in many places in the Wissahickon formation.

Except for the presence of garnet in certain layers, the Wissahickon formation and the metabasalt flows in the southeastern part of the Hanover-York district conform to the "green schist" facies of metamorphism, and show a coarse crystallization of albite, quartz, muscovite, and chlorite. The metabasalt contains also uralitic hornblende. Like the garnets, the coarse albite metacrysts in the albite-chlorite schist of the Wissahickon formation are postcrystalline in respect to the streamline of inclusions (see pl. 10, *D*), but are paracrystalline to the mica and chlorite crystallization. A border of clear albite around some of the cores with helicitic inclusions indicates a renewal of crystallization during late stages of folding. The mica flakes and albite grains are paracrystalline with the recumbent folding. Crystallization continued during the shearing out of these folds and the formation of foliation layers. The transverse cleavage is the latest structure and tends to shear out the earlier formed mica layers. Crystallization continued even after the development of this cleavage, for coarse porphyroblastic muscovite, chlorite, and chloritoid (see pls. 11, *A* and 12, *B*) are not disturbed by the transverse cleavage.

The albite-chlorite schist of the northwestern part of the Wissahickon area is finer grained schist of the "green schist" facies. The foliation is more closely folded, the dips are steeper, and the transverse cleavage is better developed. This zone, as well as that to the southeast, contains ilmenite in well-crystallized rods and thin laminae, which in many places, are included in chlorite and clinochlore porphyroblasts. It is possible that these minerals may have been derived from earlier minerals of higher rank, either biotite or staurolite, although no relics of these minerals have been found.

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 of still finer grain. Except porphyroblasts of chlorite with spongiform ilmenite centers, which suggest retrogression from a mineral of higher rank, the Marburg schist contains no garnets or any relics of a higher metamorphic min-

[53] Grübenmann, Ulrich, and Niggli, Paul, Die Gesteinsmetamorphose, pp. 397–413, Berlin, 1924.

[54] Eskola, P., The mineral facies of rocks. Norsk geol. tidsskr., vol. 6, pp. 143–194, 1930.

[55] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district, Pa., U. S. Geol. Surv. Bull. 799, pp. 27–38, 1929.

eral facies. 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 partly sheared out the muscovite and chlorite, which are paracrystalline with the folding.

In general in the Hanover-York district intensity of metamorphism decreases from southeast to northwest, as is shown by the smaller size of grains and the absence of biotite and garnet in the northwestern part of the Wissahickon formation and in the Marburg schist. In the northeastern part of the Marburg schist and in the area of Wissahickon schist northwest of Brownton, the crystallinity is much coarser than it is along the strike to the southwestward. The rocks contain porphyroblasts of muscovite, chlorite, and chloritoid, and resemble the schists in the adjoining parts of the McCalls Ferry quadrangle. The porphyroblasts (pl. 12, *B*) are oriented at angles that intersect the transverse cleavage, and are unbent, hence are later than this cleavage. This last fact shows that crystallization continued after the development of the transverse cleavage.

The porphyroblastic crystallization that occurred late in the folding, or after it, is not restricted to the rocks of the Martic overthrust block. In the Stoner overthrust block in the York quadrangle, the fine-grained Harpers phyllite of low-rank progressive metamorphism contains muscovite porphyroblasts (pl. 3, *A*), which intersect the steeply dipping cleavage at an angle, and, therefore, are later than the cleavage. The Antietam quartzite of the East Prospect syncline contains irregular porphyroblasts of biotite (pl. 4, *B* and *C*), which are visible to the unaided eye. The coarse biotite in places shows bands of chlorite, and the chlorite appears to have formed earlier than the biotite. In the Strickler anticline, which lies north of and is overridden by the Stoner overthrust, biotite is visible in the Antietam quartzite only under the microscope.

East of the York quadrangle on the Susquehanna River from a point near Pequea northwestward to Star Rock, biotite is the characteristic mineral developed in the Wissahickon formation. From a point north of Star Rock to the edge of the Martic thrust block, the schists of the Glenarm series contain muscovite and chlorite rather than biotite. The biotite zone on Susquehanna River is in strike with the part of the York quadrangle that extends northwestward from Brogueville Station to Rockey, in which coarse-grained porphyroblasts in the schists are muscovite and chlorite rather than biotite. This area of schists containing coarse-grained porphyroblasts developed late in the metamorphism of the region, is related to the larger area in which the rocks of the Martic overthrust block and the underlying Paleozoic rocks are of high metamorphic intensity. This intensity reaches a maximum on the south and southwest flanks of the Mine Ridge anticline. There the Antietam quartzite is a medium- to coarse-grained quartzose schist containing biotite and albite. These two minerals are present also in places in the Conestoga limestone. This metamorphism in the Paleozoic rocks wanes rapidly northwest of the Mine Ridge anticline. Southwest of Susquehanna River it diminishes less rapidly in the rocks of the Martic overthrust block. Biotite dies out a few miles southwest of Safe Harbor, but porphyroblasts of muscovite and chlorite, decreasing in size toward the southwest, are found in the Wissahickon and Marburg schists of the York quadrangle.

ORIGIN OF THE ALBITE

Albite-chlorite schist with coarse albite metacrysts constitutes most of the Wissahickon formation in the Hanover-York district and has a wide regional distribution. It extends from a point a mile east of Schuylkill River southwestward across Pennsylvania, a distance of 60 miles, and continues 50 miles farther southwestward in Maryland. At Susquehanna River, the belt is 15 miles wide on the northwest side of the Peters Creek quartzite. In describing the albite-chlorite schist in the McCalls Ferry and Quarryville quadrangles, E. B. Knopf and the writer [56] concluded that the soda of the albite was not derived from a magmatic source but came from the original sediment. An analysis of albite-chlorite schist [57] collected 1 mile south of Shenks Ferry Station shows a potassa content (5.36 percent) greatly in excess of soda (1.68 percent). The Harpers and Antietam sedimentary formations of that area also contain albite, and have similar high ratios of potassa to soda and relatively high percentages of lime,[58] which is present as calcite. In the albite-chlorite schist facies of the Wissahickon formation, the lime occurs in the silicate, epidote. Although the analysis of the albite-chlorite schist shows a high percent (5.36) of K_2O in comparison with the average content (3.60 percent)[59] of a normal shale, the percentage of soda is not abnormal for an arkosic sediment. The writer regards the wide distribution of the albite-chlorite schist of the Wissahickon formation as a further argument against enrichment by replacing sodic solutions.

In describing the Wissahickon schist from the vicinity of Prettyboy dam, Singewald [60] concludes that "the albite was formed from original constituents of the schist that were taken into solution and redeposited as albite."

[56] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district, Pa., U. S. Geol. Survey Bull. 799, p. 32, 1929.
[57] Idem., p. 31.
[58] Idem., p. 49.
[59] Clark, F. W., Analyses of rocks and minerals, 1880–1914: U. S. Geol. Surv. Bull. 591, p. 23, 1915.
[60] Singewald, J. T., Weathering and albitization of the Wissahickon schist at Prettyboy dam, Baltimore County, Maryland; Geol. Soc. America Bull., vol. 43, p. 463, 1932.

Albite schists in the southwestern part of the Dalradian series in Scotland and northeastern Ireland are associated with limestone and chlorite-epidote schists. Like the albite schists of York County, Pa., they have a relatively high soda content. Bailey and McCallien[61] conclude that the albite is the result of an original chemical feature of the mud and is not due to magmatic permeation. This view was expressed earlier by Clough,[62] Bailey[63] and Tilley[64] in regard to the albite schists of Scotland. The reasons given by Bailey and McCallien for their view are "the wide distribution and great bulk of the albite-schists," and their association with ferromagnesian, soda-lime sedimentary rocks. They consider that these rocks together with the albite schists are products of the erosion of a complex of igneous rocks containing soda, lime, and ferromagnesian constituents. They recognize local impregnation near granitic bodies but do not ascribe the regional development of albite schists to such a cause. These albitic rocks, however, are metamorphosed[65] wherever they occur in Scotland and Ireland, as they are in the Hanover-York area; and the possibility of metasomatic origin of the albite should be considered. Gilluly[66] has discussed in detail the literature of spilitic rocks and theories of their origin. In Eastern Oregon[67] the Clover Creek greenstone comprises altered volcanic flows and pyroclastic rocks which include quartz keratophyre (a felsic effusive rock containing albitic feldspar), spilite, albite diabase, keratophyre and quartz keratophyre tuff and breccia, and meta-andesite. Gilluly concludes that the rocks have been albitized by metasomatic processes and the more calcic feldspars replaced by the soda feldspar, albite. The analyses[68] of the Clover Creek greenstone show a high percentage of soda and, without exception, very low potassa, in which respect the greenstone does not resemble the Wissahickon formation. The volcanic rocks are the effusive equivalents of soda-rich quartz diorite which is regarded as a source of soda-rich hydrous solutions.

The albite-chlorite schist in Pennsylvania and Maryland is associated with albitic greenstone, meta-andesite, and metabasalt, but is not related to any soda-rich intrusives. These effusive rocks lie 20 miles northwest of gabbro, diorite, and pyroxenite intrusive bodies that are low in soda. The intrusive rocks form the southeastern border of the crystalline belt of Maryland and Pennsylvania and may be genetically related to the extrusive rocks. The Sykesville granite of Maryland, which intrudes the greenstone flows, is not a sodic granite. In view of these facts, as well as of the regional extent of albite-chlorite schist and its high percentage both of potassa and of soda, it does not seem probable that the presence of albite is due to enrichment by replacing solutions, but rather that it was derived from original constituents of the sediments.

The coarse-grained albite-chlorite schist resembles in appearance the schistose metabasalt with which it is associated in the southwestern part of the Hanover-York district. The mineral constituents of the two rocks are similar except for the uralitic hornblende, a larger amount of epidote, and a lesser amount of muscovite in the metabasalt. The albite-chlorite schist may be in part derived from pyroclastic material related to the metabasalt flows and metamorphism may have destroyed all evidence of such an origin. An albite schist veined with albite pegmatite in Connecticut is described by Agar[69] who says that "granitization" accompanied and partly succeeded the last crumpling.

RELATION OF ALBITE PORPHYROBLASTS TO THE CRYSTALLIZATION OF THE SCHISTS

As previously mentioned, the two structures in the schists of the Hanover-York district are: a "transposition cleavage" parallel to the older *S*-plane which is crumpled and cut by a younger transverse cleavage across the *S*-plane. In the writer's opinion, after a study of the thin sections of the schists of the Wissahickon formation, not all the albite grains were formed at the same time. Some albite (pl. 10, *D*) was formed contemporaneously with the muscovite of the ground mass, which runs through the grains as inclusions; but, the streamlines of inclusions in some grains are inclined to the direction of the older *S*-plane, showing that the grains have been rotated somewhat by later folding. A late stage of albite crystallization is seen in the clear borders, which surround centers that contain the inclusions. In other specimens albite occurs in two generations; the older albite grains are deformed, but others that formed later in the metamorphism are not. In some thin sections the streamlines of inclusions in albite grains show a crumpling that is not alined with the foliation in the ground mass; and in the writer's opinion this lack of continuity indicates that the albite grains were displaced after their crystallization.

Similar rotation of albite grains during folding was described in the McCalls Ferry-Quarryville report,[70] where examples of albite porphyroblasts that had been

[61] Bailey, E. B., and McCallien, W. J., The metamorphic rocks of northeast Antrim: Royal Soc. Edinburgh Trans., vol. 58, pt. 1, pp. 164–167, 1933–34.

[62] Clough, C. T., and others, The geology of Cowal: Scotland Geol. Survey Mem., p. 40, 1897.

[63] Bailey, E. B., The metamorphism of the South-West Highlands: Geol. Mag., vol. 60, p. 325, 1923.

[64] Tilley, C. E., Metamorphic zones in the Southern Highlands of Scotland: Geol. Soc., London Quart. Jour., vol. 81, pp. 108, 112, 1925.

[65] Bailey, E. B., and McCallien, W. J., op. cit., p. 168.

[66] Gilluly, James, Keratophyres of Eastern Oregon and the Spilite problem: Am. Jour. Sci., 5th ser., vol. 39, pt. I, pt. II, vol. 29, 1935.

[67] Gilluly, James, Geology and mineral resources of the Baker quadrangle, Oregon: U. S. Geol. Survey Bull. 879, pp. 21–26, 1937.

[68] Idem, (Bull. 879), p. 25.

[69] Agar, W. M., Petrology and structure of Salisbury-Canaan district of Connecticut: Am. Jour. Sci., 5th ser., vol. 23, No. 133, pp. 44–48, 1932.

[70] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district of Pennsylvania: U. S. Geol. Survey Bull. 799, pp. 29–30, 1929.

displaced in respect to the matrix were described. The minerals of the inclusions were relict minerals included in the albite porphyroblasts during their growth. The coarse-grained variety of albite-chlorite-muscovite schist (pl. 11, *B*) in the southeastern part of the area and in Maryland contains albite metacrysts with relict minerals of a metamorphic facies dissimilar to that of the host rock. The inclusions comprise garnet, staurolite, and biotite, which are minerals of higher metamorphic rank than the chlorite and muscovite of the matrix, and record a change in metamorphism during the formation of the schist.

Singewald [71] also interprets the crumpled streamlines of inclusions in the albite porphyroblasts of the Baltimore County area as relict minerals, but doubts that the angular discordance with the groundmass is due to rotation during folding.

Knopf [72] stated that in crystalline schists, "a valuable criterion of the relation between deformation and crystallization is given by porphyroblasts filled with inclusions." To illustrate, she describes a biotite schist from Connecticut which contains streamlines of black dust in the matrix and in the biotite, and in which "the biotite porphyroblasts are displaced with respect to the matrix, indicating that movement has been renewed to the extent of displacing the already quietly formed host." An example of porphyroblastic growth during crystallization and differential displacement is shown in plate 15, *A* and *B*. The rock is a muscovite-chlorite schist from Tucquan, Pa. The specimen and the thin section were cut normal to the regional lineation and parallel to the direction of the slip. In the garnet porphyroblasts the schistosity, outlined by black dust lines, is shaped in spiral curves. These curves indicate that the garnet rolled during its growth. A similar rotated garnet porphyroblast is described by Mügge [73] and is reviewed by Gilluly.[74] The rolling recorded in the garnet and the slipping along the planes of the foliation in the schist have a geological significance that is called to our attention by Gilluly in this review where he states that "Although the recorded translation in each schist plane may be small, when these differential motions are integrated through a thick packet of schist planes, the total displacement of the top of the formation with respect to its base may well amount to many times the thickness of the schist measured normal to the schistosity—hence in this sense a schist may represent a distributed overthrust."

[71] Singewald, J. T., Jr.: Weathering and albitization of the Wissahickon schist of Prettyboy dam, Baltimore County, Maryland: Geol. Soc. Amer. Bull., vol. 43, pp. 457–460, 1932.

[72] Knopf, E. B., and Ingerson, E.: Structural Petrology, Geol. Soc. America Mem. 6, p. 109 and pl. 13, figs. 2–3, 1938.

[73] Mügge, O., Bewegungen von porphyroblastics in phylliten und ihre messung. Neues Jahrb. für Min. Geol. und Pal., Beilage-Band 61. Abt. A, pp. 469, 1930.

[74] Gilluly, James, Report of the committee on structural petrology, Nat. Research Council, pp. 52–57, 1938.

Cloos [75] mentions rotation of albite porphyroblasts in a specimen of "Antietam mica schist" from a point 3 miles north of Marticville, Pa. He says that during folding the mica laminae are broken and folded and that "the albite inclusions furthermore indicate still more rotation and no relation to the cleavage planes. It may be that albitization has fixed a former structure and preserved it, or that the albite grains have been rotated farther than the new cleavage planes."

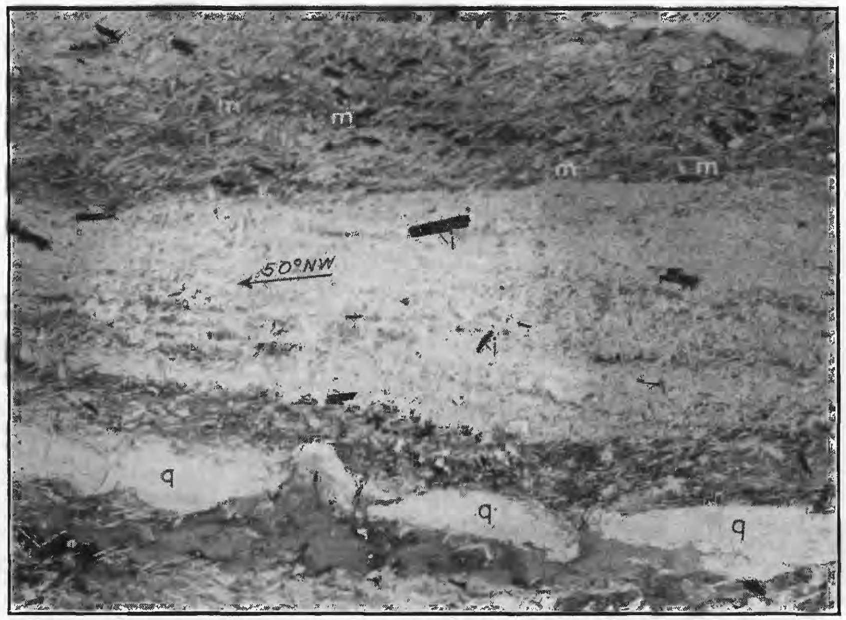
Ingerson[76] has made petrofabric studies of albite trends in the "Port Deposit granodiorite complex" and associated rocks in Maryland and of an albite schist from Peters Creek, Pa. The albite porphyroblasts in these rocks contain inclusions of muscovite whose direction he calls "albite trends," and he says that the albite trends are not relict structures but are controlled by the lattice of the feldspar grains. His second conclusion is that the albite trends "are indirectly related to the present fabric of the rock, in that the cleavages controlling the trends have been developed in the zone of the *S*-planes of the rock"; or, in other words, the inclusions grew along the cleavage planes that were parallel to the axis of folding. He ascribes the formation of the muscovite inclusions to "late hydrothermal solutions permeating the plagioclase along the planes of greatest accessibility."

The evidence presented by Ingerson seems to justify these conclusions for the rocks he described, but the writer questions the regional application of the term, "similar trends," as it is used in another one of Ingerson's conclusions: "Since there are similar trends in the plagioclase porphyroblasts in all of the rocks of Ordovician age and older in this region, their presence cannot be used as a criterion of age relations."

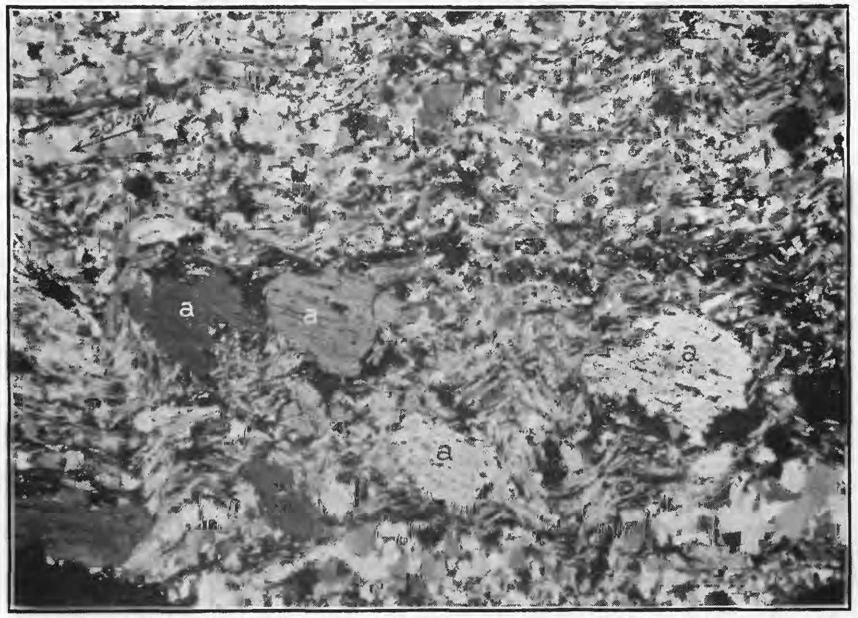
Because of the evidence given previously, the writer believes that albite porphyroblasts were formed at several stages during deformation. In some places the inclusions are relict structures, and in others the albite grains were rotated during later folding. Rocks in which the porphyroblasts contain minerals of higher metamorphic rank than those of the matrix are cited to support the argument against the conclusion that all inclusions in albite grains were formed by late hydrothermal solutions; for if this were so, the hydrothermal solutions should have formed minerals in the groundmass similar to those included in the albite metacrysts. Petrofabric studies of the type made by Ingerson are helpful in elucidating the metamorphic history of crystalline schists, but similar studies accompanied by detailed field work over a much wider area should be carried on before generalizations can be made as to the

[75] Cloos, Ernst, The application of recent structural methods in the interpretation of the crystalline rocks of Maryland, Maryland Geol. Survey, vol. 13, pp. 88–92 and pl. 9, fig. 1, 1937.

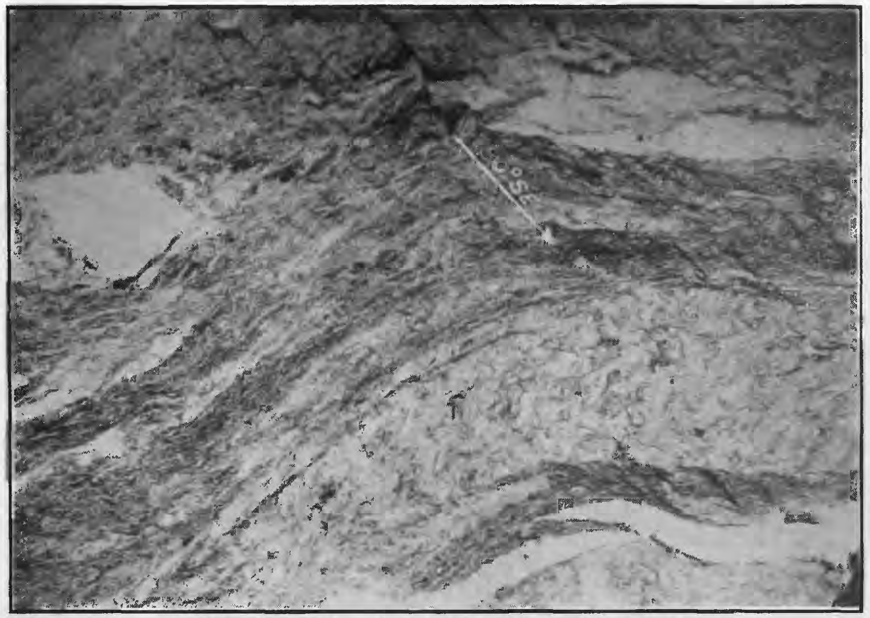
[76] Ingerson, Earl, Albite trends in some rocks of the Piedmont: Am. Jour. Sci., 5th ser., vol. 35–A, pp. 127–141, 1938.



A. MUSCOVITE-CHLORITE SCHIST 1 MILE SOUTH OF SPRINGVALE.
Quartzose lenses (q); coarse muscovite porphyroblasts (m); ilmenite (i). × 6½.



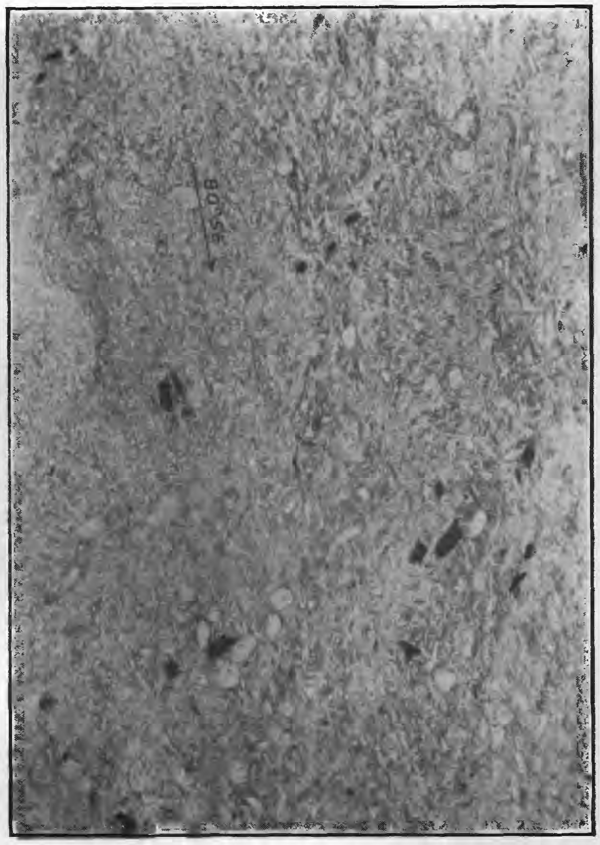
B. COARSE-GRAINED ALBITE-CHLORITE-MUSCOVITE SCHIST, 1 MILE SOUTH OF ANSTINE.
Shows paracrystalline folding. Coarse albite metacrysts (a). Foliation dips 20° NW. Crossed nicols. × 8½.



C. GRAPHITIC QUARTZITE, 1 MILE SOUTH OF SEITZLAND.
Shows recumbent fold (f) whose axial plane dips 40° NW., and transverse cleavage that dips 80° SE. × 6.

A. MARBURG SCHIST. THREE-QUARTERS OF A MILE NORTH OF CRALEY.

Muscovite-chlorite-albite-quartz schist with quartzose (lighter) layers. Cleavage dips 85° SE. × 6.

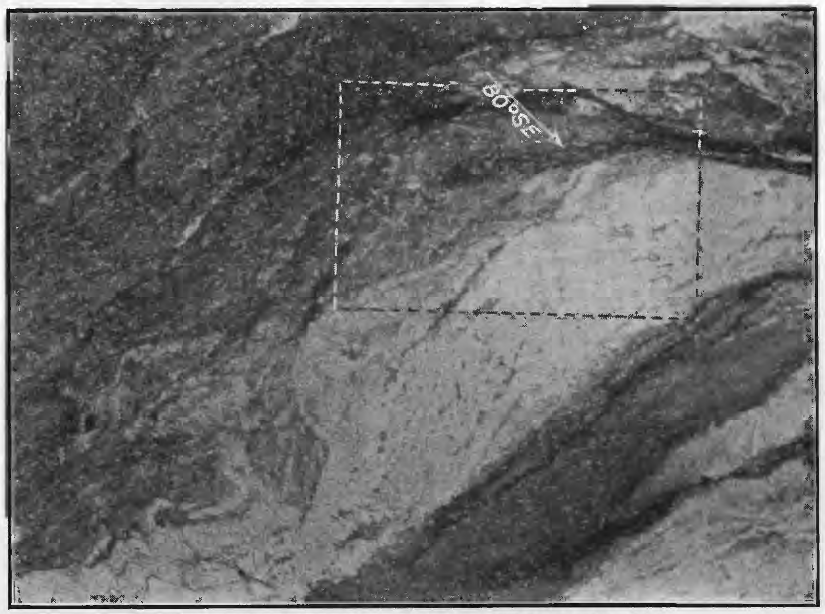


B. MARBURG SCHIST, 1 MILE NORTH OF WINDSOR.

Chlorite-albite-quartz schist showing transverse cleavage dipping 80° SE. Ilmenite (block prisms) and muscovite porphyroblasts (light-colored laths) are not bent by the cleavage. × 9.

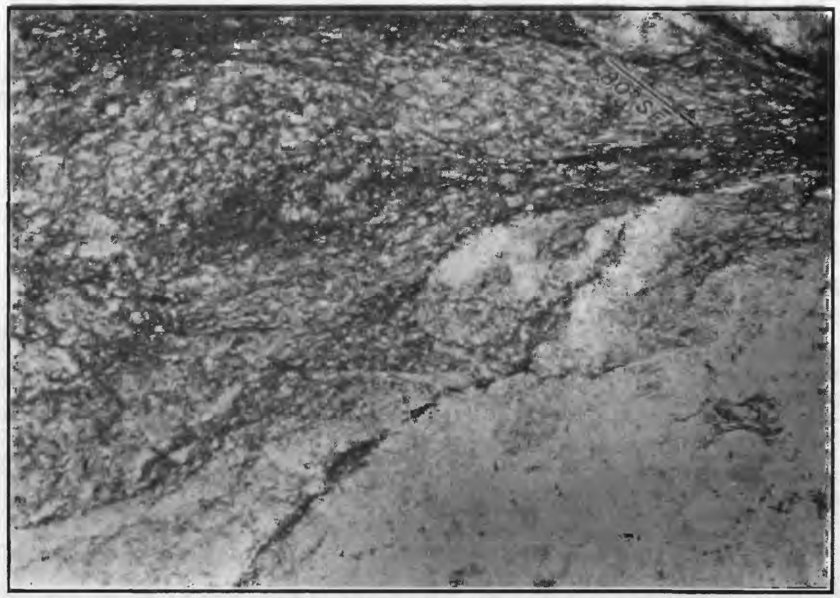
C. MARBURG SCHIST, FROM MARBURG.

Muscovite-chlorite schist with quartzose layer (white). Section from arch of a close fold, showing transverse cleavage dipping 80° SE. × 27.

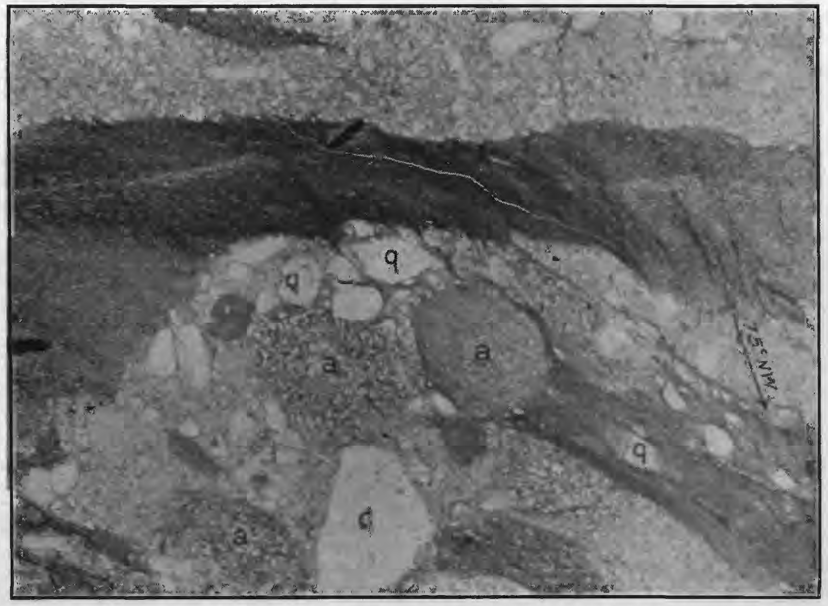


A. MARBURG SCHIST, 1 MILE NORTH OF MARBURG.

Fine-grained muscovite-chlorite-quartz schist, showing close folding and "transposition" cleavage. Transverse cleavage dips 80° SE. Field in rectangle enlarged in *B*. × 9.



B. MARBURG SCHIST, SHOWING GREATER DETAIL IN PART OF THIN SECTION ILLUSTRATED IN *A*. × 27.

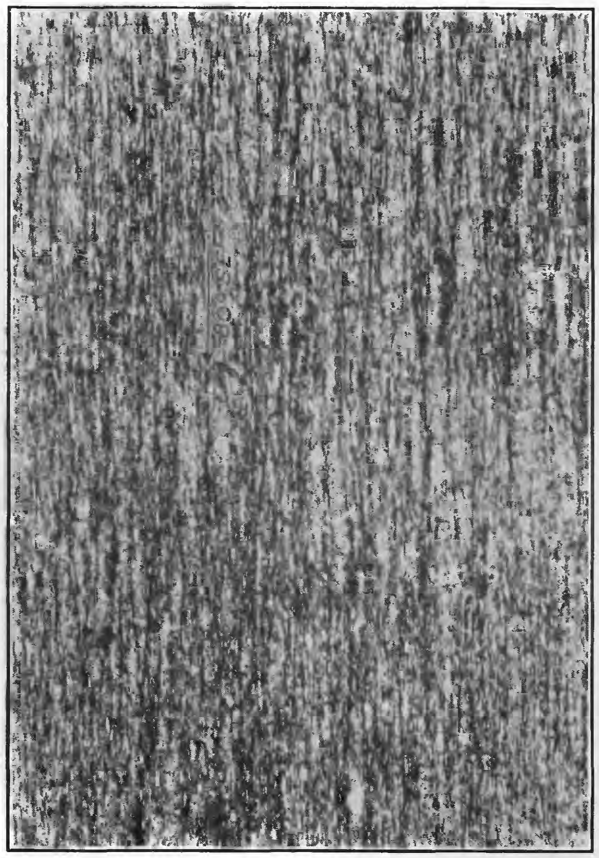


C. QUARTZITE ASSOCIATED WITH MARBURG SCHIST, 1½ MILES SOUTHEAST OF DALLASTOWN.

Contains blue quartz grains (q) and aggregates (a) that are composed of subangular quartz in fine black dust. Cleavage in slate band (dark) dips 75° NW. × 6½.

A. CHLORITOID-MUSCOVITE-QUARTZ SCHIST FROM SAUBEL HILL.

Chloritoid shows as dark prisms arranged in sheaves. Cleavage dips 80° NW. × 27.



B. CHLORITOID-MUSCOVITE-QUARTZ SCHIST FROM HOFFACKER VALLEY.

Chloritoid shows as dark fibers. × 27.

C. BANDED CHLORITE-MUSCOVITE-QUARTZ SCHIST, HALF A MILE SOUTH OF FREYSVILLE.

Dark prisms are ilmenite. Transverse cleavage dips 80° NW. × 6½.

metamorphism and the tectonic history of the Glenarm series and the adjoining Paleozoic rocks.

In the work on the McCalls Ferry-Quarryville district, the writers[77] pointed out two major problems, namely, the variability of metamorphism in the rocks of the Glenarm series, and the localization of high metamorphic intensity in the area around Mine Ridge and southwestward. Much of the summary of conclusions given in that report (see pp. 139–140) is reaffirmed here.

This abnormal relation of strong metamorphic intensity in the Paleozoic rocks with lower intensity in the pre-Cambrian thrust block suggests that the dominant metamorphism in both Paleozoic and Glenarm strata was subsequent to the overthrust. This idea is confirmed by the character of the thrust plane so far as observation of it has been possible. The thrusting appears to have taken place under conditions that were favorable to molecular rearrangement and metamorphism.

The strong degree of metamorphic intensity localized in the autochthonous Paleozoic beds near the surface emergence of the fault plane suggests that the increased load produced by the weight of the thrust block may have had some influence in the metamorphism. But the conditions for crystalloblastic alteration could hardly have been produced by depth of burial alone. The normal load of sediments upon the Conestoga formation at the time of metamorphism could hardly have amounted to as much as 10,000 feet. Even if this normal load were considerably increased by the weight of the thrust block the additional load could not have been sufficient to cause anything but a cataclastic metamorphism in the autochthonous Paleozoic sediments or in the displaced thrust block.

The only feasible explanation for a folding and metamorphism of the thrust block that would inhibit or obliterate the effects of cataclastic metamorphism is a rise of geothermal gradient. A localized rise of geothermal gradient suggests the influence of highly heated underlying igneous rock, and such thermal influence combined with the locally increased load of the faulted rock would doubtless account for the peculiar concentration of intense metamorphism in the overridden Paleozoic rocks. The hypothesis is alluring, but has been insusceptible of proof except insofar as the extensive tourmalinization and pegmatitization of the Paleozoic rocks indicate the passage of magmatic emanations from an underlying igneous intrusion.

Pegmatite veins have penetrated only into the Lower Cambrian Hellam conglomerate member of the Chickies quartzite on the south flank of Mine Ridge. More recently pegmatite has been observed near Safe Harbor, Pa. In a quarry opened during the construction of the dam and power plant of the Safe Harbor Water Power Co., a Triassic diabase dike cuts Antietam quartzite and the overlying Vintage dolomite; and at the contact with diabase the dolomite is baked and contains knots of epidote. A pegmatitic differentiate of the diabase exposed in the quarry contains coarse pink feldspar. North of Safe Harbor in the cuts of the Pennsylvania Railroad, albite-biotite schist of the albite-chlorite schist facies of the Wissahickon formation contains similar pegmatite veins, which cut across the foliation of the schist, and are inclined to the plane of the cleavage. These relationships indicate that this pegmatite is later than the folding of the schist and may be related to the Triassic diabase of the Safe Harbor dike rather than to an older (Paleozoic) igneous intrusion associated with the regional metamorphism.

Intrusive rocks are widespread in the schists of the Glenarm series in Maryland and Pennsylvania southeast of the Hanover-York district and the Mine Ridge area. The granitic intrusives are the Sykesville granite and Port Deposit granite. As stated on page 48 of this report, both Ingerson and the writer believe that these granitic bodies were intruded before the regional metamorphism. The hydrothermal emanations genetically related to these granites may have had some influence in the metamorphism of the schists of the Glenarm series; but it is more probable that thermal effects of a younger granite, not visible at the surface in Pennsylvania, produced the strong metamorphism and the late porphyroblastic crystallization in the rocks of the Mine Ridge belt and the region to the southwest.

SUMMARY

Heat and pressure, produced during folding, have metamorphosed the rocks of the Martic overthrust block with a general decrease in intensity from southeast to northwest. Folding and metamorphism took place over a long period. Metamorphic intensity has been reversed in certain zones, the earlier metamorphism being of higher rank than the later. Metamorphism was contemporaneous with the folding, and outlasted it, as shown by porphyroblasts in large part undisturbed by the latest structure—the transverse cleavage—which tended to shear out the earlier-formed minerals.

This latest metamorphism, which reached its maximum intensity to the east in the McCalls Ferry-Quarryville district, has produced a coarser crystallization of the schists in the eastern part of the York area than southwestward along the strike, and has affected also the Harpers phyllite and Antietam quartzite in the Cabin Creek and Stoner overthrust blocks, which lie northwest of the Martic overthrust block. Metamorphic intensity wanes rapidly northwest of the Stoner overthrust in the Hanover-York Valley and in the Pigeon and Hellam anticlines northwest of the valley. In these anticlines the Harpers phyllite, which is the best index of metamorphism of the rocks of that area, is a fine-grained rock. The Vintage dolomite shows development of muscovite in its schistose beds; and the Conestoga limestone, where most closely folded north of the Stoner overthrust, contains muscovite in the argillaceous layers.

ORIGIN OF THE WISSAHICKON FORMATION, MARBURG SCHIST, AND ASSOCIATED QUARTZITES

The Wissahickon formation in the Hanover-York district has been described as made up of three types of

[77] Knopf, E. B., and Jonas, A. I., op. cit., pp. 118–141, 1929.

schist with infolded quartzites: (1) albite-chlorite-muscovite schist containing layers of opaque dust, (2) albite-chlorite-muscovite schist containing coarse albite metacrysts in which epidote occurs as inclusions in the albite and in the groundmass, and (3) chlorite-muscovite schist containing chloritoid. These mineral differences are due to original differences in composition. Albite and chloritoid do not occur together, for chloritoid is produced in rocks that contain abundant alumina and relatively scant magnesia, potassa, and lime. The albitic Hoosac schist and the chloritoid Rowe schist,[78] of western Massachusetts and Vermont, also record in the minerals of their crystallization a similar original difference in composition. Like the types of schist in the Hanover-York region, these rocks in the Taconic quadrangle are infolded and cannot be mapped separately.

Chloritoid schists occur also in the Marburg schist which, southwestward along the strike in Carroll and Frederick Counties,[79] Md., show evidence of tuffaceous origin. There, blue, purple, and green schists or phyllites containing chloritoid, or chlorite, and muscovite, in part show tuffaceous structure and are interlayered with aporhyolite, metabasalt flows, and tuffs. In the Hanover-York district, a tuffaceous character is not evident in the Marburg schist. South of the Jefferson syncline, the blue, purple, and green phyllitic schists of the Marburg are closely similar in appearance and composition to the tuffaceous phyllites of Maryland; and the Marburg schist may be in part of pyroclastic origin.

Because chloritoid is a highly aluminous mineral, it has been regarded, like staurolite, as indicative of metamorphosed sedimentary rocks. However, bentonite,[80] which is altered volcanic ash or tuff, is also high in alumina. Bentonite is composed largely of clay minerals formed by the alteration and devitrification of glassy volcanic tuff, much of which contains detrital material. If the chloritoid schists in this area were derived from volcanic material which had undergone such chemical changes before metamorphism, a volcanic origin for these chloritoid schists should not be inconsistent.

In Maryland tuffaceous phyllites, in strike with the Marburg schist of the Hanover-York district, lie northwest of the marble-volcanic belt that extends through Maryland northeastward into the Hanover-York district. In the York area the Wissahickon formation surrounds the northeast end of the metabasalt and grades northwest into the Marburg schist. The chloritoid schists of the Wissahickon formation also may represent tuffaceous layers in that formation. The opaque dust layers and rods, largely ilmenite and iron oxide, found in part of the Wissahickon formation, are original constituents of the rock. Likewise, certain tuffaceous phyllites in Maryland contain the layered opaque dust and the crystalline form of ilmenite. This fact suggests that the schists of the Wissahickon formation that have a high content of titanium and iron oxide may be of volcanic origin.

The Marburg schist which lies northwest of the Wissahickon formation is less metamorphosed and finer grained than the Wissahickon formation. The Marburg resembles the Wissahickon formation in containing chloritoid schist, albite-chlorite schist, and chlorite-muscovite schist with opaque dust layers. Southwest in Maryland, similar fine-grained chloritoid schists or phyllites and chlorite-muscovite schist layered with fine opaque dust, in part ilmenite, have tuffaceous characteristics. These schists, however, may be the finer grained equivalent of the albite-chlorite schist facies of the Wissahickon formation. The rhyolitic flows and tuffaceous phyllites in Maryland are interbedded with red and purple arkosic quartzite, sericitic quartzite, blue and purple phyllite with siliceous layers, and coarser conglomeratic quartzite that contains grains and pebbles of blue quartz, feldspar grains, and angular green argillaceous fragments. These quartzites are believed to be stream-worked tuffs mixed with detrital quartz and appear to be a part of the volcanic series. Gilluly[81] describes a similar mixing of clastic and pyroclastic material in the Burnt River schist and Elkhorn Ridge argillite of Oregon.

The quartzites in the Wentz syncline, especially the conglomeratic variety, resemble conglomerates, which are regarded as in part tuffaceous, farther southwest in Maryland. The conglomerate layers of the quartzite contain flattened pebbles of fine sericite and quartz in which the subangular quartz grains (see pl. 13, *C*) suggest a volcanic origin.

Although it is more intensely metamorphosed, the conglomeratic quartzite in the Wissahickon formation, south of Felton and of Graydon, resembles the quartzite associated with the Marburg schist. The muscovite in the matrix is coarser and the argillaceous pebbles are sheared out in the direction of the cleavage. This conglomeratic quartzite may be equivalent to the quartzite associated with the Marburg schist.

AGE AND RELATIONS OF THE ROCKS OF THE MARTIC OVERTHRUST BLOCK

The rocks of the Martic overthrust block belong to the Glenarm series, and the northwestern part of the block is included in the Hanover-York district. The Glenarm

[78] Prindle, L. M., and Knopf, E. B., The geology of the Taconic quadrangle: Amer. Jour. Sci., 5th ser., vol. 24, pp. 288–289, 1932.

[79] Jonas, A. I., and Stose, G. W., Geologic map of Frederick County and adjacent parts of Washington and Carroll Counties, Maryland: Maryland Geol. Survey, 1938.

[80] Ross, C. S., Altered Paleozoic volcanic materials and their recognition: Am. Assoc. Petroleum Geologists Bull., vol. 12, pp. 146–149, 164, 1928.

[81] Gilluly, James, Geology and Mineral Resources of the Baker quadrangle, Oregon: U. S. Geol. Survey Bull. 879, p. 12, 1937.

series is composed of crystalline schists, which lie southeast of the Paleozoic limestones and dolomites of the Hanover-York Valley and the underlying arenaceous Lower Cambrian rocks. The Paleozoic limestones and dolomites form the synclinal valleys in the vicinity of York, Hanover, Lancaster, Quarryville, and the Chester Valley and the Great Valley northwest of the Triassic rocks.

The points of difference between the schists of the Glenarm series in the Martic overthrust block and the Paleozoic rocks to the northwest are: The schists of the Martic overthrust block are dominantly of argillaceous and arenaceous facies, whereas the Paleozoic rocks are largely limestones and dolomites with arenaceous beds in the lower part. As far is as known, the rocks of the Glenarm series contain no fossils. The Paleozoic rocks are fossiliferous. In the Hanover-York district and southwest in Maryland, volcanic flows and tuffs make up a large part of the Glenarm series; and in the area farther southeast, intrusive rocks are widespread. In contrast, no Paleozoic effusive or intrusive rocks occur except for basalt flows and diabase dikes found near Jonestown, Pa., and scanty pegmatite in the basal Cambrian near Mine Ridge. The metamorphism of the rocks of the Glenarm series continued over a long period and was intimately connected with the folding. The latter part of their metamorphic history was shared by the Paleozoic rocks to the northwest, especially in the vicinity of the Mine Ridge anticline.

Along the contact between the schists of the Glenarm series and the Paleozoic rocks from Schuylkill River southwestward to the Maryland line in the southwestern part of the Hanover quadrangle, the schists of the Glenarm series overlie Harpers phyllite, Antietam quartzite, and Vintage dolomite of Lower Cambrian age, and Conestoga limestone of Ordovician (?) age. On the east side of Frederick Valley, Md., the schists of the Glenarm series overlie Lower Cambrian Antietam quartzite and Upper Cambrian Frederick limestone. The contact of the Glenarm series on Paleozoic rocks, therefore, is not conformable. Evidence given in the chapter on the structure of the district shows that the schists of the Glenarm series were probably thrown into recumbent folds during the movement which brought them forward to lie on the Paleozoic rocks. This recumbent folding was an earlier phase of the deformation that arched and folded the Paleozoic rocks and the underlying pre-Cambrian rocks together with the overlying crystalline schists of the Glenarm series. The direction of the fold axes in the schists of the Glenarm series conforms with that of the underlying Paleozoic rocks and, therefore, offers no evidence to prove either that the rocks of the Glenarm series were moved to their present position by overthrusting or that they were originally deposited where they now occur.

AGE OF THE ROCKS OF THE GLENARM SERIES

In a preliminary paper on the marble-volcanic area of Carroll and Frederick Counties, Md.,[82] the quartzites of the Sugarloaf syncline were regarded as Lower Cambrian, and their occurrence in synclines of the marble-volcanic series was cited as proof of the pre-Cambrian age of the Glenarm series, of which the marble-volcanic series is a part. Later work in the area has led the writer to regard the lower beds of these quartzites as a part of the volcanic series and as equivalent in part to similar quartzites associated with the Marburg schist in the Hanover-York district.

In Sugarloaf Mountain, Md., thick white pure quartzites overlie ferruginous quartzites that are interbedded with slates and arenaceous rocks, which are probably tuffaceous in part. The uppermost beds of white quartzite cap the highest peak of the mountain, and lower quartzite beds form the crest of the mountain north of the peak and of Furnace Ridge. 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. As their Cambrian age has not been proved, this evidence for the pre-Cambrian age of the Glenarm series has little weight.

In Virginia two areas of fossiliferous slate of Cincinnatian age are infolded with the schists of the Glenarm series along the axis of the Peach Bottom syncline. The Quantico slate lies along the border of the Coastal Plain 18 miles southwest of the District of Columbia at Potomac River. At the western side the slate overlies greenstone schist and granite gneiss. On the east these slates are overlapped by sedimentary formations of the Coastal Plain. The Arvonia slate lies in north-central Virginia farther to the southwest. The basal conglomerate of the slate unconformably overlies the Columbia granite and the Peters Creek quartzite which the granite intrudes. Rock similar to the Columbia granite extends in discontinuous areas northeastward to the Potomac River, where it passes into the Sykesville granite of Maryland between the mouths of Rock Creek and Rock Run on the Potomac River. In Virginia, therefore, the Columbia granite and the Peters Creek quartzite, which is a part of the Glenarm series, are pre-Cincinnatian, that is, pre-Eden. The Peters Creek quartzite is considerably older than Cincinnatian, as is shown by the fact that it was intruded by granite, uplifted, and eroded before the Arvonia slate was deposited. Therefore, the upper part of the Glenarm series, that is, the Peters Creek quartzite and Wissahickon formation, cannot be equivalent to the Martinsburg shale, as has been suggested,[83] because the Martinsburg shale, whose basal

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

[83] Mackin, J. H., The problem of the Martic overthrust and the age of the Glenarm series in southeastern Pennsylvania: Jour. Geology, vol. 43, p. 358, 1935. Miller, B. L., Age of the schists of South Valley Hills, Pa.: Geol. Soc. America Bull., vol. 46, p. 754, 1935.

beds are of Trenton age, is largely Eden in age and belongs in the lower part of the Cincinnatian series.

The Cardiff conglomerate and the Peach Bottom slate of Maryland and Pennsylvania were included in the Glenarm series and designated as pre-Cambrian [84] in 1923 by the Federal Survey and Maryland Geological Survey because the writers of the paper cited were unable to find any evidence of unconformity at the base of the Cardiff conglomerate. Further, although Lesley [85] reported that specimens of *Buthotrephis flexuosa* were found in the Peach Bottom slates, the specimens cannot be located, and no other fossils have been obtained from the area.

In a recent report on York County, Pa.,[86] which includes part of the Peach Bottom syncline, Stose and Jonas give their reasons for concluding that the Cardiff conglomerate and Peach Bottom slate are probably of Ordovician age and are not part of the Glenarm series. As bedding folds are plainly visible in some of the slate quarries, obviously, the folding of the Peach Bottom slate has not destroyed the bedding. The Peach Bottom slate occurs in the same syncline with the Quantico and Arvonia slates, which contain fossils of Ordovician age, and the slates are lithologically similar and both the Peach Bottom and Arvonia slates are underlain by quartzose conglomerate. The Cardiff conglomerate and Peach Bottom slate, therefore, are regarded as of probable Ordovician age and not as a part of the underlying Glenarm series.

A summary of views held previous to 1923 on the age relations of the rocks of the Glenarm series, with full references, is given by Knopf and Jonas in a preliminary paper on the Glenarm series.[87]

In reports on Baltimore County [88] and on the McCalls Ferry-Quarryville district,[89] these writers replied to the view of Hawkins [90] that the sedimentary rocks that flank the Avondale-Kennett anticline are of the same sedimentary series as those of Chester Valley, and that the metamorphic effects of a large buried intrusive mass, which has altered the series at Avondale, has barely affected the series in Chester Valley. Bascom in a footnote to the geological map of Pennsylvania, 1931, and later in the Coatesville-West Chester Folio [91] expressed the belief that a belt of schist half a mile or more wide on the south side of Chester Valley is of Ordovician age but that the Wissahickon formation to the southeast of this narow belt is pre-Cambrian. Mackin,[92] like Hawkins, is of the opinion that the Glenarm series is Paleozoic rather than pre-Cambrian in age, and that the Wissahickon formation is the metamorphosed equivalent of the Martinsburg shale. One of his reasons for this view is that volcanic rocks of post-Beekmantown age at Jonestown, Pa., overlie Beekmantown limestone and underlie the Martinsburg shale, just as the volcanics of the Glenarm series overlie the Wakefield marble. The proof that the Peters Creek quartzite and hence the Wissahickon schist are not of Martinsburg age was given above. The presence of volcanic rocks in both series seems to the writer to be a coincidence and not evidence of equivalent age upon which to base a correlation.

Mackin concludes also that the steep contact of limestone and schist south of Chester Valley is a normal contact because the South Valley hills are parallel in general with the ridge composed of the steeply dipping Chickies quartzite on the north side of Chester Valley. The South Valley hills near Coatsville do trend parallel to the valley; but east of Quarryville, in the Quarryville quadrangle, the hills south of the valley are an échelon to the direction of the valley and not parallel to it. Consequently, if these hills are the erosional expression of underlying beds, as claimed by Mackin, the evidence indicates an unconformable contact of schist and limestone and not the conformable contact he interpreted.

Miller [93] in 1935 expressed views similar to those of Mackin on the Paleozoic age of the Glenarm series, the equivalence of the Wissahickon schist and the Martinsburg shale, and the conformability of the schist with the limestone of Chester Valley. In stating that between the Schuylkill and Susquehanna Rivers the Wissahickon schist was everywhere in contact with Conestoga limestone, he ignored the fact that in places the Wissahickon schist, as is shown on the map of the McCalls Ferry-Quarryville quadrangles, is in contact with Lower Cambrian Vintage dolomite, and also that west of the Susquehanna River, in the Hanover-York district, the Wissahickon schist is in contact with Lower Cambrian Harpers schist, as had been shown on the Geological map of Pennsylvania published in 1931. Miller, like Mackin, assumed that the dip of foliation in the Wissahickon schist represented the dip of folded beds in an undisturbed stratigraphic sequence, a concept which has been shown to be untenable.

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[84] Knopf, E. B., and Jonas, A. I., Stratigraphy of the crystalline schists of Pennsylvania and Maryland: Am. Jour. Sci., 5th ser., vol. 5, pp. 40–62, 1923.

[85] Lesley, J. P., Age and position of the Peach Bottom slates, Am. Phil. Soc. Pr., vol. 18, pp. 364–369, 1879.

[86] Stose, G. W., and Jonas, A. I., Geology and Mineral Resources of York County, Pa.: Pennsylvania Topog. & Geol. Survey Bull. C 67, pp. 95–102, 106, 1939.

[87] Knopf, E. B., and Jonas, A. I., op. cit., pp. 40–63.

[88] Knopf, E. B., and Jonas, A. I., Baltimore County, Maryland Geol. Survey, pp. 180–183, 1929.

[89] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry Quarryville district, Pennsylvania: U. S. Geol. Survey Bull. 799, pp. 21–24, 33–35, 1929.

[90] Hawkins, A. C., Alternative interpretations of some crystalline schists in southeastern Pennsylvania: Am. Jour. Sci., 5th ser., vol. 7, pp. 355–360, 1924.

[91] Bascom, Florence, and Stose, G. W., U. S. Geol. Survey Geol. Atlas, Coatesville-West Chester folio (No. 223), pp. 5–6, 1932.

[92] Mackin, J. H., Jour. Geol., vol. 43, op. cit., p. 358, 1935.

[93] Miller, Benjamin L., Age of the schists of the South Valley Hills, Pennsylvania: Geol. Soc. America Bull., vol. 46, pp. 715–756, 1935.

In comments on Miller's paper, Stose and Bucher [94] questioned some of his observations and conclusions. The writer wishes to draw attention, also, to a paper by Knopf [95] that has a bearing on the apparent conformability of the schists of the Glenarm series with the adjoining Paleozoic rocks. Knopf [96] describes how transverse slipping or folding may obscure or completely obliterate a stratigraphic unconformity as well as a structural discordance and poses an obvious question, "Why assume that the general lack of obvious structural evidence of such a thrust would prove its nonexistence?"

Cloos,[97] as a result of structural studies along the Susquehanna River near Port Deposit, Md., distinguished in the crystalline schists of the area two structures that he calls flow cleavage and fracture cleavage. He considers these to be the same as the two structures found in the Ordovician (?) Conestoga limestone and the folding in both series to be post-Conestoga. He regards the foliation in these intrusive rocks as a primary structure and says that the intrusives in part crosscut the schists they intrude. He concludes that the igneous rocks near Port Deposit were intruded after the last folding of the rocks in the area and, therefore, are of post-Conestoga age. The same conclusions were stated by Cloos,[98] Hershey,[99] and Marshall [1] in a report that contains a general discussion of the crystalline rocks of Maryland together with detailed studies of the "Port Deposit granodiorite complex" and the volcanic complex of Cecil County, Md. Cloos adds that, although the foliation in the "Port Deposit granodiorite" roughly parallels the general regional strike and flow cleavage, the foliation in the complex is largely primary flow structure and that "the foliation [in the granite] was formed during intrusion of the magma and after flow cleavage was imposed on the sediments." [2] In an earlier report Cloos [3] concluded that the foliation in the granite at Ellicott City and in the adjoining gabbro is a primary flow structure. In the later report [4] his conclusion is similar, and he adds that the flow lines in the granite at Ellicott City "point straight upward and obviously indicate the direction of flow directly." The writer studied the granite at Ellicott City during her work on Baltimore County and believes that its steeply dipping linear structure was produced not by primary flow but by a steep-axis folding, which took place after its intrusion, and, further, that the nearly horizontal joints in the granite east of Ellicott City are tension joints at right angles to the tectonic axis. She believes also that the gabbro adjoining the granite at Ellicott City, which is older than the granite, has a cleavage developed later than the primary banding and that the intrusion of the gabbro antedated the regional deformation. She agrees with the conclusions of Cohen,[5] who states fully [6] his reasons for considering "that the cleavage in the gabbro is of metamorphic origin" and that the present shape of the gabbro mass and the secondary structures are the result of flowage during the metamorphism which it shared with the crystalline rocks of the Piedmont area.

As a result of a reconnaissance of the Port Deposit area, the writer believes that the foliation of the igneous rocks in that area likewise was produced during the folding that affected both these intrusive rocks and the schists in which they are intruded. This view is supported by the fabric studies of Ingerson [7] on the Port Deposit granite. He writes: the "mica and quartz fabrics of the Port Deposit granite and the zenoliths were produced by metamorphism of the intrusive and its zenoliths after intrusion rather than by working over of the inclusions during intrusion." He contrasts the Port Deposit granite with the Uncle Sam quartz monzonite porphyry near Tombstone, Ariz., in which the quartz fabric of the inclusions is unlike that of the host, and hence concludes that the quartz monzonite has not been subjected to regional metamorphism since its intrusion.

While working for the Maryland Geological Survey from 1919 to 1938, the writer mapped in detail the Sykesville granite from its northeast end in Harford County, Md., southwestward across Baltimore, Carroll, and Howard Counties. The Sykesville granite intrudes the Peters Creek quartzite and an amphibolite schist in a belt that parallels the Peach Bottom syncline from Harford County, Maryland, to Potomac River. The granite injected the adjoining schists and contains fragments of them and of the amphibolite schist. Although primary flow structures may be seen in the Sykesville granite, more prominent is a later foliation, which the granite shares with the adjoining rocks of the Glenarm series

94 Stose, G. W., Comments on paper entitled "Age of schists of the South Valley Hills, Pa.," by B. L. Miller: Geol. Soc. America Bull., vol. 46, Supplement, pp. 2021–2026, 1936; Bucher, W. H., idem., pp. 2029–2030.

95 Knopf, E. B., Recognition of overthrusts in metamorphic terranes: Amer. Jour. Sci., 5th ser., vol. 30, pp. 198–209, 1935.

96 Idem., p. 206.

97 Cloos, Ernst, and Hershey, H. G., Structural age determinations of Piedmont intrusives in Maryland: Nat. Acad. Sci. Proc., vol. 22, pp. 71–80, 1936.

98 Cloos, Ernst, The application of recent structural methods in the interpretation of the crystalline rocks of Maryland: Maryland Geol. Survey, vol. 13, pt. 1, pp. 27–98, 1937.

99 Hershey, H. G., Structure and age of the Port Deposit granodiorite complex: Maryland Geol. Survey, vol. 13, pt. 2, pp. 109–146, 1937.

1 Marshall, John, The structures and age of the volcanic complex of Cecil County, Md.: Maryland Geol. Survey, vol. 13, pt. 4, pp. 189–211, 1937.

2 Cloos, Ernst, op. cit., p. 31.

3 Cloos, Ernst, Structure of the Ellicott City granite, Maryland: Nat. Acad. Sci. Proc., vol. 19, pp. 130–138, 1933.

4 Cloos, Ernst, The application of recent structural methods in the interpretation of the crystalline rocks of Maryland: Maryland Geol. Survey, vol. 13, pt. 1, p. 41, 1937.

5 Cohen, C. J., Structure of the metamorphosed gabbro complex at Baltimore, Md.: Maryland Geol. Survey, vol. 13, pt. 5, pp. 215–236, 1937.

6 Idem., p. 233–234.

7 Ingerson, Earl, Comparison of the fabrics of zenoliths and adjacent intrusive rock (abstract): Am. Mineralogist, vol. 23, pp. 8–9, 1938.

that it intrudes. In part of the area[8] the Sykesville granite has a steep-axis structure and a series of prominent joints at right angles to the linear direction of the fold axes. In many places where the fold axes dip steeply, the surface outcrop exposes joints lying at right angles to the lineation and shows a cross section of the folded foliation of the granite and injection gneiss. The Sykesville granite was intruded before the development of the steep-axis structure and has shared the regional deformation with the adjoining schists of the Glenarm series.

Because the Conestoga limestone was involved, the folding and metamorphism of the Glenarm series was post-Conestoga in age, that is, post-Lower Ordovician. If, as the writer believes, the granite at Ellicott City and the adjoining gabbro, the Port Deposit granite, and the Sykesville granite were intruded before the post-Conestoga orogeny, these igneous rocks cannot be of post-Lower Ordovician age, as is claimed by Cloos. The date of this orogeny has no bearing on the age of the Glenarm series or of the intrusive rocks except that it indicates that all the rocks are older than the post-Ordovician deformation which affected them.

The writer concludes, therefore, that the rocks of the Glenarm series, which underlie the Cardiff conglomerate and Peach Bottom slate, are pre-Cincinnatian; that their original composition is not equivalent to that of Paleozoic rocks to the northwest; that their contacts with the Paleozoic rocks are not conformable; and that the discordant character of their contacts is caused not by sedimentary overlap but by overthrusting. The pre-Cambrian age of the Glenarm series is not proved; but, as no positive evidence to the contrary has been found, the series tentatively is assigned pre-Cambrian age in this report.

TRIASSIC SYSTEM

NEWARK GROUP

GENERAL DESCRIPTION

The Newark group comprises a wide belt of red sandy rocks that extend from New Jersey southwestward across Pennsylvania and Maryland into Virginia. This belt, which has a maximum width of about 30 miles at the Delaware River, is 10 miles wide in the vicinity of the Hanover quadrangle. It covers the northwest third of the quadrangle and extends farther northwestward for about 3 miles into the Carlisle quadrangle. The rocks are mostly red, but beds of light-gray sandstone and greenish to light-yellow arkosic sandstone are common in the lower part.

In the Hanover quadrangle the average dip of these red rocks is 30° NW., though the dip ranges locally from 10° to 50°. The total computed thickness of these rocks in the Hanover and Carlisle quadrangles, as determined from the dips of the beds and the width of the outcrop, is about 16,000 feet. The sediments were deposited in a long, narrow inclosed depression or basin that trended northeastward. Residual sand and clay, which were derived from the weathering of an uplifted mass of Cambrian quartzites and older rocks to the southeast, were washed by rains and floods into the inclosed basin. The sediments were first deposited in the southeastern

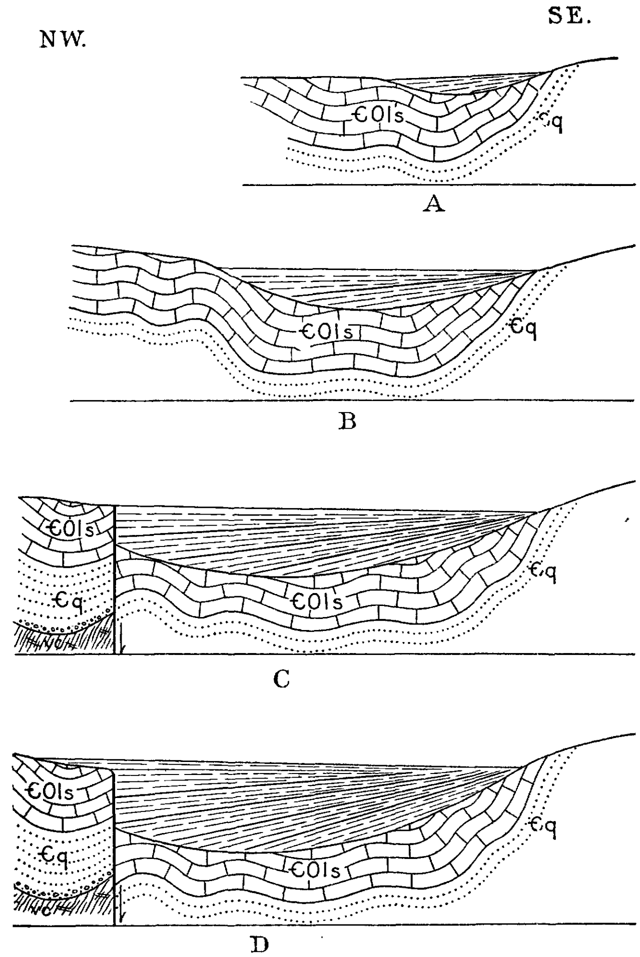


FIGURE 22.—Ideal progressive sections across the Triassic basin in the Fairfield-Gettysburg, Pa., area, illustrating mode of deposition of sediments as floor of basin subsided during progressive sinking and down-faulting, and resulting northwesterly dips of beds. €Ols, Cambrian and Ordovician limestones; €q, Cambrian quartzite; vc, pre-Cambrian volcanic rocks.

part of the basin but later spread progressively farther west as the basin was deepened by the gradual sinking of the floor on the west side. Only a part of the total thickness of the strata, therefore, will be found at any one place. The postulated mode of deposition is illustrated in figure 22.

Two formations of the Newark group are distinguished in the Hanover quadrangle—the lower, called the New Oxford formation, composed of red sandstone, shale, and many light-gray interbedded arkosic sand-

[8] Jonas, A. I., Tectonic studies in the crystalline schists of southeastern Pennsylvania and Maryland: Am. Jour. Sci., 5th ser., vol. 34, pp. 383–384, 1937.

stones; and the upper formation, called the Gettysburg shale, composed almost wholly of red shale and soft red sandstone.

NEW OXFORD FORMATION

NAME AND DISTRIBUTION

The New Oxford formation was named from New Oxford, Adams County, where the Triassic formations in southern Pennsylvania were first studied in detail and their thickness determined. The formation occupies a belt about 5 miles wide in the northwest third of the Hanover quadrangle. Owing to the greater resistance of the gently dipping Triassic sandstone and conglomerate in comparison with the adjacent Paleozoic limestones and shales, the southeast edge of the belt is for the most part sharply marked by a low escarpment. That the red beds once extended somewhat farther southeast is shown by small remnants of red calcareous sandstone preserved in pockets in the limestone in quarries northwest of York, 1 mile southeast of the present edge of the Triassic area. This sandstone contains marble pebbles. South of Abbottstown the Triassic rocks lap onto the slope of the Pigeon Hills. Northeastward, the southeast edge of the New Oxford formation passes just north of La Bott and Thomasville, and thence bends more northeasterly to the northeast corner of the Hanover quadrangle. Its northwest edge is marked approximately by the winding course of Conewago Creek.

CHARACTER AND THICKNESS

The New Oxford formation consists of red to purplish-red sandstone and shale but is characterized by many intercalated beds of light-gray or greenish-yellow arkosic sandstone. Most of the arkosic beds are crumbly sandstone containing many grains of white kaolinized detrital feldspar, glassy quartz, and sparkling flakes of detrital light-colored mica. Some of the beds contain small rounded quartz pebbles and weather to sand and gravel. Interbedded with the arkosic layers are red shale and soft red micaceous sandstone, which underlie small valleys between ridges and spurs of the harder arkosic sandstone and produce alternate red and yellow streaks in the soil and along country roads.

In the vicinity of the Pigeon Hills, a conglomerate at the base of the formation is composed chiefly of round white quartz pebbles in a red sand matrix. (See pl. 15, *C*.) This conglomerate is coarsest and thickest south of Abbottstown, at the widest part of the Pigeon Hills, where it forms rocky ledges that make a low front ridge or bench along this part of the mountain. This bench rises 100 feet above the general level of the Triassic upland. This bed thins eastward and ends 1 mile southwest of La Bott. The pebbles of the conglomerate were evidently derived from rocks of the Pigeon Hills, for they include epidote, slate, volcanic rocks, and quartzite. East of Abbottstown, other thin beds of conglomerate, two of which have been mapped, are stratigraphically slightly higher. The abrupt hill made by one of these beds of conglomerate is very noticeable on the highway (U. S. 30) at Farmers. A prominent bed of conglomerate half a mile north of La Bott has been traced eastward 3 miles to a point where other conglomerate beds come in at a still higher stratigraphic level. This distribution of conglomerate shows that the shore current moved northeastward.

The top of the New Oxford formation is placed where beds of light-gray arkosic sandstone end or become scarce and red shale predominates. This boundary is more or less arbitrarily mapped and probably is not exactly the same horizon in the sedimentary sequence in this district as it is in the type area to the southwest. Assuming that beds are not duplicated by strike faulting, the thickness of the formation as determined from width of outcrop and dip of beds in the Hanover quadrangle is about 6,000 feet.

UNCONFORMITY AT THE BASE

The New Oxford formation rests unconformably on the Paleozoic rocks that in large part constitute its floor. In the northeastern part of the Hanover quadrangle, the New Oxford overlaps the end of a belt of Kinzers formation and at the northeast corner lies on Vintage dolomite. Southwestward, it lies chiefly on Ledger dolomite but overlaps the Kinzers at several places. Northwest of West York, a small erosional remnant of Triassic sandstone is preserved on a hill of shale of the Kinzers formation. To the southwest, the New Oxford formation overlies Ledger dolomite nearly as far as Thomasville where the two formations strike almost at right angles to each other. West of Thomasville the Triassic rocks overlap the shale of the Kinzers formation, which there strikes at right angle to the contact; and farther west they lie on Vintage dolomite. On the flanks of the Pigeon Hills the New Oxford formation rests on the Cambrian quartzites and the pre-Cambrian metabasalt.

AGE AND CORRELATION

Few fossils have been found in the Newark group, and those that are known are of continental type that corresponds to the terrestrial character of the red sediments. Fragments of silicified wood have been found in plowed fields north of this area in the vicinity of Elizabethtown, Bainbridge, and York Haven. These were identified by Wherry[9] as *Araucarioxylon vanartsdaleni*. Fragments of several other species of fossil trees have been collected from these beds farther east. Reptilian bones and teeth have been collected near Emigsville just north of the district; and Wherry has reported fish remains from the rocks farther east. Small phyllopod crustaceans (*Estheria ovata*, Lea) were collected by the

[9] Wherry, E. T., Silicified wood from the Triassic of Pennsylvania: Acad. Nat. Sci. Philadelphia Proc. 64, pp. 367-369, 1912.

writers in a dark-gray to black shale near the base of the formation half a mile west of Farmers, and at a point east of New Oxford, 1 mile west of the Hanover area. These fossils suggest a correlation of the New Oxford formation with the Upper Triassic of Europe. This determination by fossils accords with the general age determination based upon the relation of the New Oxford to other formations and to structures of known age.

The formation has the same general lithologic characters as the Stockton formation, the lower formation of the Newark group in the eastern part of the State. The two formations are recognized as more or less equivalent; but the Lockatong formation, which overlies the Stockton, thins out near Elverson, Pa., so that exact equivalence cannot be established.

GETTYSBURG SHALE

NAME AND DISTRIBUTION

The Gettysburg shale is named from Gettysburg, Adams County, where it is typically exposed. In the Hanover quadrangle the shale is present only in the northwest corner, northwest of East Berlin, Dars School, and Davidsburg. Its outcrop in the quadrangle is about 3 miles wide. In the extreme northwest corner, the shale is intruded by a thick diabase sill, which is about 1 mile wide in outcrop. The sill is part of the Gettysburg sill described in the Fairfield-Gettysburg folio [10] and the report on York County, Pa.,[11] and extends northeast and southwest for many miles.

CHARACTER AND THICKNESS

The Gettysburg shale in the type area consists chiefly of soft red shale and some soft red micaceous sandstone. In the Hanover quadrangle, conglomerate beds occur in the midst of the red shale. To the north in the New Cumberland quadrangle, these coarser strata thicken and are composed of massive hard sandstone and lenticular beds of conglomerate that make the Conewago Hills and, therefore, are named the Conewago conglomerate member. These resistant beds make a low ridge, Airy Hill, which crosses the northwest corner of the Hanover quadrangle and is the southwest extension of the Conewago Hills.

The red shale adjacent to the diabase sill in the northwest corner was altered when the diabase was intruded and was hardened by the heat of the molten mass into a dense, tough purplish-black porcelanite containing irregular knots of green epidote. The diabase and baked shale are harder than the unaltered red rocks and consequently make a line of broad, low hills. Northwest of Yorkhaven, 12 miles north of this area, garnet crystals were formed in cavities left by dissolved limestone pebbles in conglomerate beds in the Gettysburg shale. (See pl. 15, *D*.)

The total thickness of the formation, which extends 3 miles northwest of the quadrangle into the Carlisle quadrangle, is estimated to be about 9,000 feet. As previously stated, the beds of the Newark group overlap one another northwestward like shingles (fig. 22) and, therefore, the total aggregate thickness of beds of the formation is not present at any place.

Molds of lozenge-shaped glauberite crystals [12] were found in the red shales at Goldenville, 12 miles west of this area. Glauberite, a sodium-calcium sulphate associated with rock salt deposits and also found on alkali flats, indicates that conditions were arid when the deposits were laid down.

AGE AND CORRELATION

Where conglomerates or pebbly sandstone do not occur, the general soft shaly character typical of the formation persists in this area. Small fossil shells identified as *Estheria ovata*, Lea, a phyllopod crustacean, were collected by the writers from a green shale in the Gettysburg shale at Middletown. The same form has been found in black shale at the base of the New Oxford formation near Farmers and to the southwest and northeast at several other places in Pennsylvania. Dinosaur foot prints have been found [13] in red sandstone of the Gettysburg shale in this region, and reptile and fish remains have been collected from equivalent beds farther east in Pennsylvania. The formation is of Upper Triassic age. It is lithologically similar to the Brunswick shale, the upper formation of the Newark group in the eastern part of the State; and the two formations are approximately equivalent.

TRIASSIC IGNEOUS ROCKS

DIABASE

GENERAL DESCRIPTION

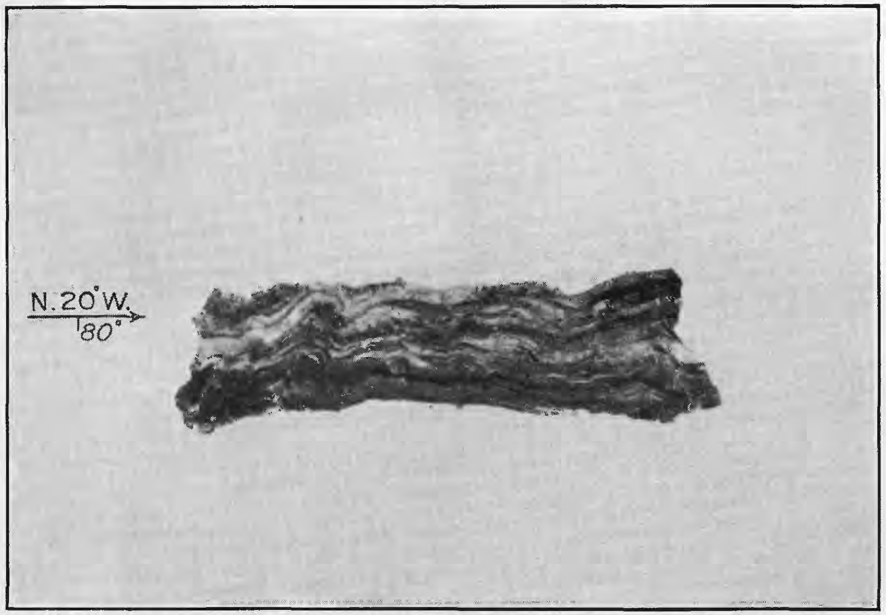
The rocks of the Hanover-York district are intruded by diabase, chiefly in the form of narrow dikes. In places the dikes make low, linear ridges strewn with residual rounded rusty tough boulders locally called "iron stones." A thick sill of diabase intrudes the red Gettysburg shale and follows the strike of the beds in a northeastward direction across the northwest corner of the Hanover quadrangle. The sill dips 40° NW. parallel with the bedding of the enclosing red shale.

[10] Stose, G. W., U. S. Geol. Survey, Fairfield-Gettysburg folio, Geol. Atlas (No. 225), pp. 11–13, 1929.

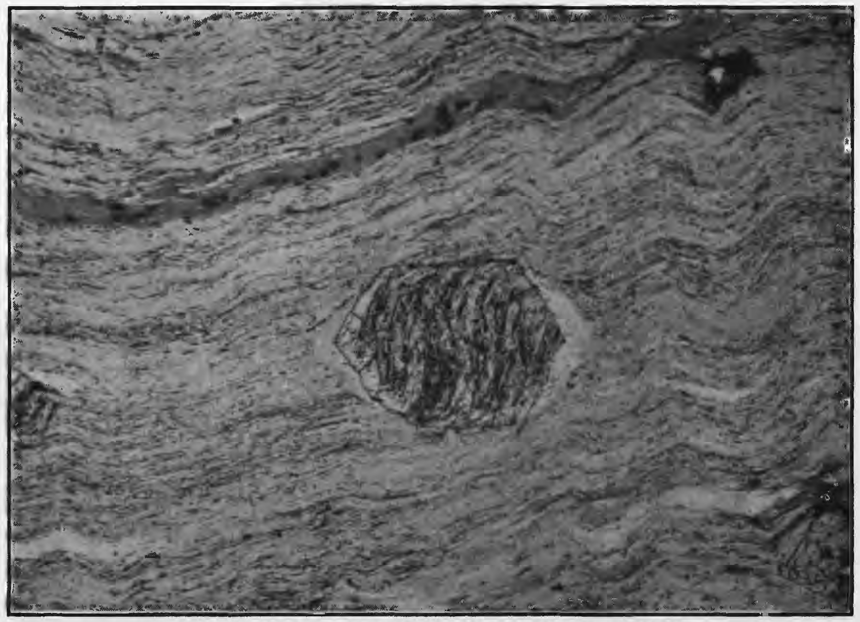
[11] Stose, Geo. W., and Jonas, A. I., Geology and mineral resources of York County, Pa.: Pa. Topog. and Geol. Survey, 4th ser., Bull. C 67, pp. 120–124, 1939.

[12] Stose, G. W., Glauberite crystal cavities in the Triassic rocks in the vicinity of Gettysburg, Pa.: Am. Minerologist, vol. 4, No. 1, pp. 1–4, 1919.

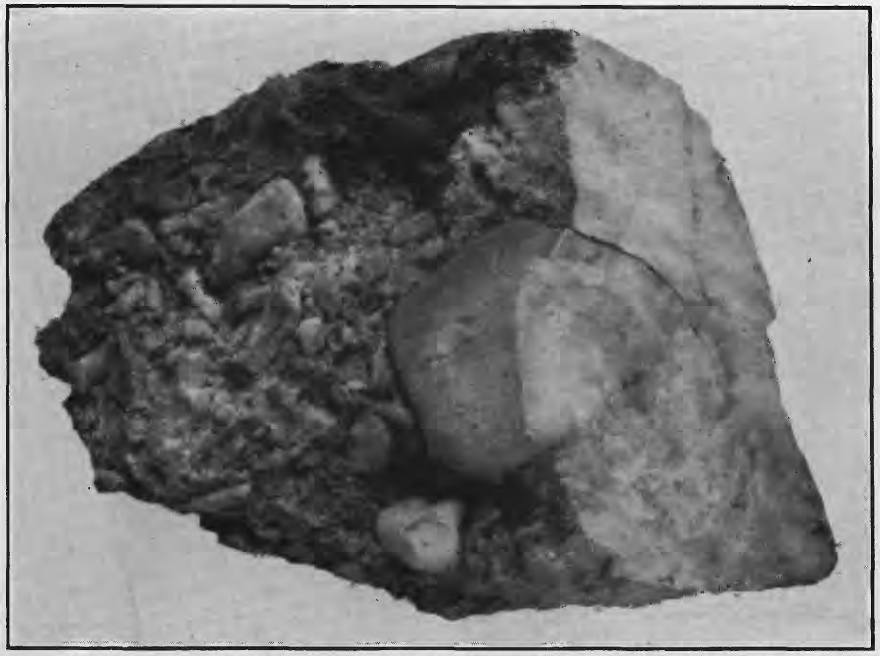
[13] Hickok, W. O., and Willard, Bradford, Dinosaur foot tracks near Yocumtown, York County, Pa.: Pennsylvania Acad. Sci. Proc., vol. 7, pp. 55–58, 1933. Cleaves, A. B., Quarry gives up dinosaur footprints after millions of years; Pennsylvania Dept. Int. Aff. Monthly Bull., vol. 4, No. 3, pp. 12–15, Aug. 1937, and No. 4, pp. 8–11, Sept. 1937.



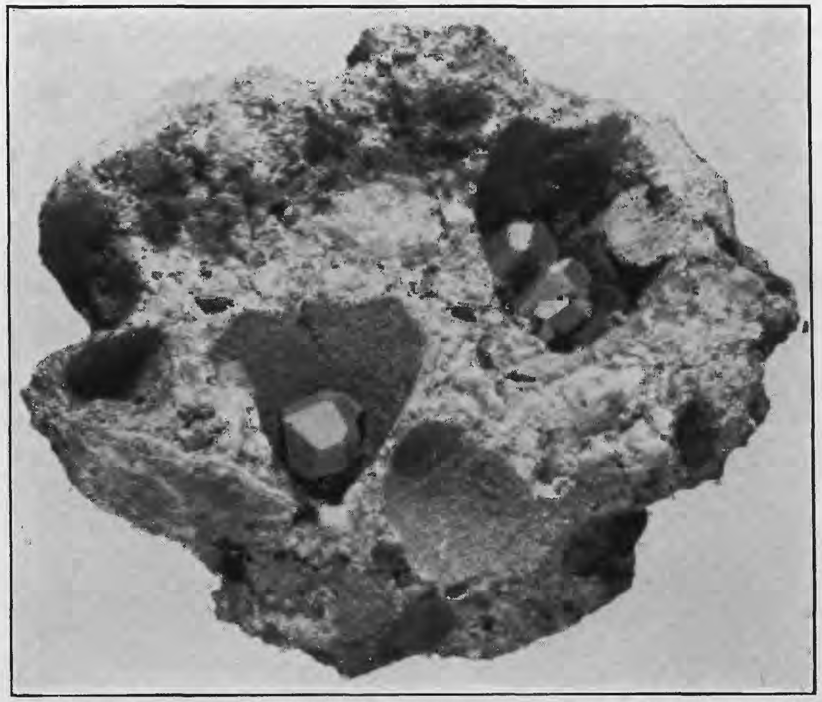
A. FOLIATION LAYERS IN GARNETIFEROUS CHLORITE-MUSCOVITE SCHIST, TUCQUAN, PA.
Recumbent folds sheared out. Natural size.



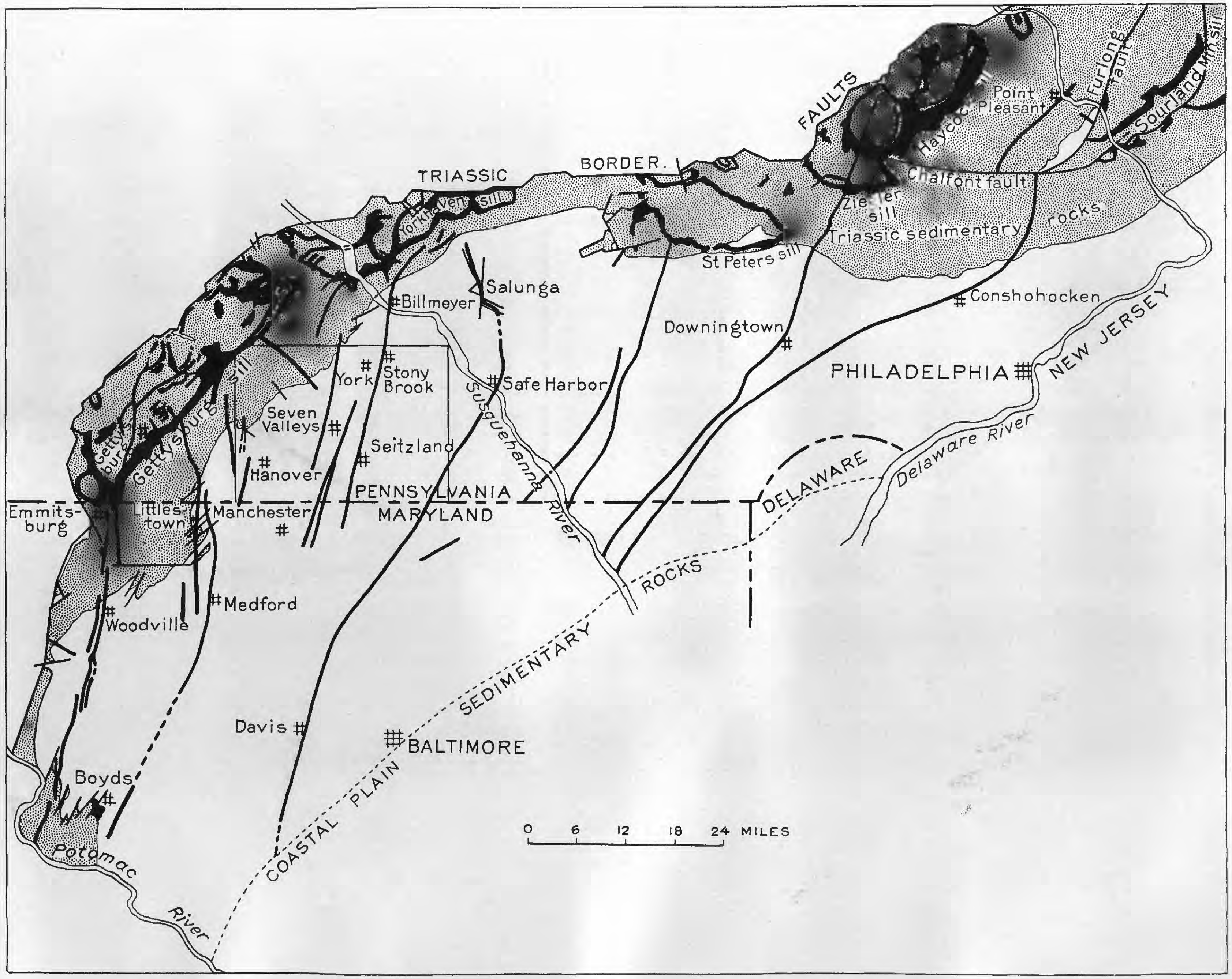
B. GARNETIFEROUS CHLORITE-MUSCOVITE SCHIST.
Thin section of specimen shown in *A*. S-shaped lines of black dust in garnet indicate rotation during growth. × 15.



C. QUARTZ PEBBLE IN CONGLOMERATE NEAR BASE OF NEW OXFORD FORMATION NORTHWEST OF LA BOTTE.
Cut through and slickensided by fault plane. Natural size.



D. GARNET (ANDRADITE) CRYSTALS IN SOLUTION POCKETS IN METAMORPHOSED CONGLOMERATE IN THE GETTYSBURG SHALE, NEW CUMBERLAND QUADRANGLE, 15 MILES NORTHWEST OF YORK.
Natural size.



SKETCH MAP OF TRIASSIC SEDIMENTARY ROCKS IN WESTERN NEW JERSEY, PENNSYLVANIA, AND MARYLAND, SHOWING DIABASE SILLS, CROSS-CUTTING BODIES, AND DIKES.

Dotted areas, Triassic sedimentary rocks; solid black areas and heavy black lines, Triassic diabase; and lighter black lines, faults. The Gettysburg sill crosses the northwest corner of the Hanover quadrangle. Hanover-York district shown by rectangle.

(Face p. 57)

At its contact with the sill the shale was baked to a hard grayish-blue rock by the heat and hot water that escaped from the injected mass. As both the diabase and the baked shale are more resistant to erosion than the adjacent unaltered red shale, they form a low ridge.

DIKES

Several diabase dikes cross the Hanover-York district. The trend of these dikes is for the most part a little west of south. The Stonybrook dike enters the area from the north, crosses the York quadrangle with several breaks and offsets, passes through Seitzland, and extends into Maryland. It makes a conspicuous ridge strewn with diabase boulders where it cuts the Conestoga limestone. Where it is well exposed in a cut along the Pennsylvania Railroad north of Stonybrook the dike is vertical and about 50 feet wide and cuts sharply across limestone beds that dip 30° SE. It is paralleled on the west by five thinner, less extensive dikes that cut both the Triassic sedimentary rocks and the older crystalline rocks. One dike splits into two south of Rockville and both branches extend into Maryland.

A dike trending S. 40° E. crosses the Triassic rocks and enters the Paleozoic limestones near Botts. In general, dikes trending southeastward are less numerous than those trending southwestward. Dikes on the western border of the Hanover quadrangle and in the area to the west trend more nearly southward. The directions of the dikes are controlled by tension cracks, which in places become faults which offset the Triassic sedimentary rocks. Two such normal faults parallel to the dike that passes through Botts, offset the Triassic sedimentary rocks near Farmers. South of Abbottstown faults that offset the basal beds of the New Oxford formation trend in general S. 10° W. and are approximately parallel to the dikes west of Hanover. In the Lancaster [14] quadrangle near Salunga (pl. 16), a diabase dike follows a normal fault trending S. 30° E.; north of Marietta Junction, the dike turns south along another fault for a half mile, then bends again southeastward along a third fault, which continues S. 20° E. across the quadrangle, then changes its direction to S. 35° W. in the northern part of the McCalls Ferry quadrangle and passes through Safe Harbor and across the southeast corner of the district and thence southwestward across Maryland. These dikes and the normal faults that they follow or parallel represent major lines of Triassic fractures. They cut across older structural lines, which are nearly at right angles to them. Many of the diabase dikes originate in or join the diabase sills to the northwest (pl. 16), cross the Triassic sedimentary rocks, and persist for many miles across the older rocks. The Conshohocken and Downingtown dikes, 35 miles east of the district, are 60 to 70 miles long; and the Safe Harbor dike extends an equal length before it, and the enclosing crystalline rocks, are covered by sediments of the Coastal Plain.

SILLS

The diabase sills, with which many of the dikes connect at their northwestern ends, coalesce to form extensive intrusive bodies in the northwestern part of the Triassic area of Pennsylvania. (See pl. 16.) The larger sills are the Haycock, Ziegler, Saint Peters, Yorkhaven, and Gettysburg. They parallel the strike of the sedimentary rocks for long distances, and then the intrusive body cuts across the strike at right angles. Most of these crosscutting bodies extend to the northwestern edge of the Triassic basin where they terminate against the faults that form the boundary of the basin. Each of these intrusive bodies, therefore, has the form of a great tilted trough bounded on the southeast side by the west-dipping sills and at the ends by the cross-cutting bodies and open at the west. The large intrusive bodies of diabase lie almost entirely outside of the Hanover-York district, but the Gettysburg sill cuts the northwest corner of the Hanover quadrangle, as shown in plate 16. This sill and the enclosing red Gettysburg shale dip 40° NW.

The probable method of intrusion of the Gettysburg sill has been discussed by Stose.[15] A similar method of intrusion was described for the Yorkhaven diabase sill,[16] which crosses the Susquehanna River 10 miles north of York. The fissures through which the diabase entered the Triassic rocks are believed to lie near the northwest edge of the basin where the greatest amount of progressive sinking and faulting occurred during Triassic deposition. The rising magma broke through the Triassic beds near the vents in the form of cross-cutting bodies, and injected the beds to the southeast in the form of sills. The magma extended still farther southeastward as dikes that followed vertical fractures in the Triassic sedimentary rocks and continued into the older underlying rocks southeast of the limits of the basin of Triassic sedimentation. Some of these dikes in the area southeast of the Triassic outcrops may have been feeders of large diabase bodies in Triassic sedimentary rocks that are now removed by erosion, but evidence is not available to support such a view.

CHARACTER OF THE ROCK

The diabase in the dikes is a fine- to medium-grained dark-gray to black rock of typical diabasic texture. The chief constituents are grayish-green plagioclase (andesine or labradorite) mostly in lath-shaped grains

[14] Stose, G. W., and Jonas, A. I., Lancaster quadrangle, Pa.: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas No. 168, p. 55, 1930.

[15] Stose, G. W., Triassic igneous rocks in the vicinity of Gettysburg, Pa.: Geol. Soc. Amer. Bull., vol. 27, pp. 625–630, 1916. Fairfield-Gettysburg folio, U. S. Geol. Survey Geol. Atlas (No. 225), pp. 11–12, 1929.

[16] Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pennsylvania: U. S. Geol. Surv. Bull. 840, pp. 41–43, 1933.

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and interstitial green augite; other minerals that can be seen only in thin section are magnetite, apatite, and a little quartz. Augite is more abundant than feldspar in the fine-grained diabase.

The diabase of the Gettysburg sill where it crosses the northwest corner of the Hanover quadrangle, is fine-grained at the borders. On the southeastern edge in the lower part of the sill, this fine-grained diabase grades upward into a lighter-gray medium-grained diabase in the center. The upper part of the sill contains a coarse- and medium-grained pink sodic differentiate of the diabase. The coarser-grained layer is about 10 feet thick and grades upward into a medium-grained pink facies. The coarser-grained variety is composed largely of pink feldspar crystals with green hornblende laths arranged in part as radiating sheaves. Epidote occurs also in sheaves and in veins. In the upper finer-grained part of this differentiate, the amount of hornblende exceeds that of feldspar. The dark olive-green crystals of hornblende are as much as 1 inch long. The fine-grained rock is cut by coarse-grained aplite. The top of the sill is typical fine-grained dark-gray diabase.

The feldspar of the pink pegmatitic facies is twinned sodic oligoclase whose composition is close to that of albite.[17] It is clouded by fine bands of saussurite parallel to the twinning lamellae and contains minute flakes of sericite. The hornblende is fibrous and penetrates the oligoclase along edges and cracks. Bluish-green hornblende, of the variety pargasite, occurs in some specimens. The pink facies contains also epidote fibers and abundant titanite in grains and crystals. The oligoclase, banded with saussurite, is an alteration produce of a more calcic feldspar. Hornblende probably is secondary to augite, although no augite was observed in the sections studied. These minerals are characteristic of light-colored diabase differentiates elsewhere. Light-colored rock composed of pink feldspar and hornblende also occurs near the top of the Yorkhaven [18] diabase sill in the Middletown quadrangle, and in the Gettysburg sill at several localities in the Gettysburg and New Cumberland quadrangles. The differentiate has been more fully described in the report on York County.[19] Near Gettysburg, Lewis noted titanite in the aplite facies. In the Saint Peters sill, the pegmatitic facies [20] is a hornblendic rock associated with magnetite ores.

In the Gettysburg sill and elsewhere these differentiates are near the upper part of the igneous body. In New Jersey, pegmatitic facies in the upper part of the Palisade diabase is ascribed by Lewis [21] and Bowen [22] to gravitative differentiation of basaltic magma. The differentiation resulted in the segregation of a part richer in feldspars, probably more sodic in composition, and rich in mineralizers, which in many places escaped into the adjoining sedimentary rocks. The normal fine-grained diabase in the chilled contact layer at the top of the sill represents original magma that solidified before differentiation took place.

[17] The minerals in the diabase were determined by J. J. Glass.

[18] Stose, G. W., and Jonas, A. I., Geology and Mineral Resources of the Middletown quandrangle, Pa., U. S. Geol. Surv. Bull. 840, p. 44, 1933.

[19] Stose, G. W., and Jonas, A. I., Geology and Mineral Resources of York County, Pennsylvania. Pennsylvania Geol. Survey, 4th ser., Bull. C 67, pp. 127–130, 1939.

[20] Smith, L. W., Magnetite deposits of French Creek, Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. M 14, pp. 35–37, 1931.

METAMORPHISM OF WALL ROCK

Above and below the sills, the adjacent red shale and sandstone are altered to a dense bluish-black porcellanite, and the lighter-colored pinkish-gray sandstone is altered to white or green quartzite. The width of outcrop in the altered rocks is usually half a mile, but where the beds dip less than 30° it is wider. These hard baked rocks grade through a narrow belt of purple shale and sandstone into the normal red rocks of the Triassic. In the northwest corner of the Hanover quadrangle, the sill and the enclosing sedimentary rocks dip 40° NW. and the outcrop of the altered rock, is only a quarter of a mile wide. The altered shale and sandstone are recrystallized and contain new minerals introduced by hot waters that escaped from the diabase. In the Hanover quadrangle, epidote and chlorite nodules weather out on the surface as round knots. In the grayish blue baked shale above the sheet, cavities and veins are filled with the white zeolite, heulandite, and green copper carbonate coats the shale in places.

In thin section, the recrystallized shale is seen to be made up of fine quartz and feldspar grains in a groundmass of felty sericite and minute granules of black iron oxide. Epidote prisms occur on the borders of heulandite. Irregular rounded nodules of green hornblende with inclusions of quartz spot the rock. The Triassic sedimentary rocks were not only recrystallized but were permeated by mineralizing solutions that contributed chiefly lime and magnesia to the formation of these minerals. The mineralizing solutions came from the magma and, during its crystalization, were released into the adjacent sedimentary rocks. The consequent reactions aided in the induration and metamorphism of the sediments.

In the New Cumberland quadrangle north of the Hanover quadrangle, limestone pebbles in conglomerate beds of the Conewago member of the Gettysburg shale have been dissolved, leaving rounded cavities that contain trapezohedral crystals of the iron garnet, andradite. (See pl. 15, *D*.) In the Gettysburg quadrangle to the west and at Dillsburg in the Carlisle quadrangle to the northwest, magnetite deposits have been formed by the replacement of limestone at its contact with the diabase.

[21] Lewis, J. V., Petrography of the Newark igneous rocks of New Jersey: New Jersey Geol. Survey Ann. Rept., 1907, pt. 4, pp. 99–167.

[22] Bowen, N. L., Adirondack intrustives: Jour. Geology, vol. 25, p. 510, 1917.

QUATERNARY SYSTEM

Alluvium.—Alluvium covers the flood plains of the larger streams in the district, but in most places it was not mapped because of its limited extent. Alluvium-covered flood plains occur at intervals along Codorus Creek and its larger branches, and along Fishing Creek and the North Branch of Muddy Creek. Between these areas of flood plains, the streams occupy steep-sided gorges with little or no alluvium. Below the junction of South Branch and East Branch of Codorus Creek, an unusually wide tract covered with gravel has been mapped. Another wide area of gravel borders the stream in the lowland south of West York and York; but it was omitted from the map, so that the intricate bedrock geology would not be hidden. Alluvium and terrace gravels are well developed and have been mapped along Conewago Creek in the northwest corner of the Hanover quadrangle.

Alluvium and soil cover the wide, flat limestone lowlands of the York-Wrightsville Valley and the lowlands at Spring Grove, Nashville, Hanover, Penn Grove, and in the Jefferson syncline. The soils of these lowlands are largely the weathering products of limestone, are exceptionally fertile, and are highly cultivated; rock outcrops are scarce.

Terrace gravels.—Terrace gravels 20 to 60 feet above the stream were mapped on flat-topped spurs in meanders of Conewago Creek, in the northwest corner of the Hanover quadrangle. Terrace gravel, 60 to 80 feet above Codorus Creek, was observed and mapped at only one place south of West York. No other terrace gravels were found at this level; but lower terrace gravels, which were not mapped, occur on many stream meanders.

No high-terrace gravels were observed in this area, but level-topped hills correspond in altitude with gravel-covered terraces in the Hellam Hills and along the Susquehanna River in the adjacent Middletown quadrangle and formerly may have been thinly covered with gravel.

GEOLOGIC STRUCTURE

The structure of the Triassic rocks in the northern part of the area and that of the Paleozoic and older rocks to the south are so different that they will be described separately. The Paleozoic rocks were compressed into close folds that trend northeastward. Many of these folds are overturned and broken by thrust faults along which the rocks have moved northwestward. The Triassic rocks, which were deposited after the Paleozoic rocks were deformed, are not folded but were tilted rather uniformly northwestward and broken into blocks that were displaced by normal faults. These faults have affected also the rocks of the Paleozoic area and thus have somewhat modified the earlier structures.

PRE-TRIASSIC STRUCTURE

GENERAL STRUCTURE

The Hanover-York district lies in the southeastern part of the belt of Appalachian folding, where the pre-Triassic rocks were recrystallized or metamorphosed as well as folded. The pre-Triassic rocks form the surface of the whole York quadrangle and three-fourths of the Hanover quadrangle. The major structural units in these rocks are the Pigeon Hills and Hellam Hills anticlinoria, Wrightsville syncline, Stoner overthrust, and the Martic overthrust. (See structure sections, pl. 1.) The Pigeon Hills anticlinorium and the Hellam Hills anticlinorium are uplifts along the same axis, and bring to the surface cores of pre-Cambrian volcanic rocks, which, with the overlying Lower Cambrian quartzose rocks, form the higher hills north of the Hanover-York Valley. (See fig. 28.) Only the southwest end of the southern (Mount Zion) anticline of the Hellam Hills anticlinorium enters the area.

The Wrightsville syncline, which incloses Lower Cambrian and Ordovician (?) limestones in the York Valley, lies south of the Mount Zion anticline and north of the Strickler anticline. In this district the Strickler anticline is in large part overridden by the Stoner overthrust. Southwest of York, in the Hanover Valley, several anticlines in the Lower Cambrian rocks occur between the Pigeon Hills anticlinorium and the Stoner overthrust. (See pls. 1 and 17.)

The Stoner overthrust block is made up of several anticlines in Lower Cambrian quartzites and slates—the Mount Pisgah, Holtz, Kraft Mill, and Berkheimer School anticlines. The East Prospect and Jefferson synclines lie near the southern edge of the Stoner block.

The Martic overthrust bounds the East Prospect syncline, Holtz anticline, and Jefferson syncline on the south. The Martic block, containing schists of the Glenarm series, has overridden the Paleozoic limestones and dolomites along the Martic overthrust. These schistose rocks were later folded into the Tucquan anticline, which crosses the southeast corner of the area, and other minor anticlines to the northwest. The Yoe and Wentz synclines enclose Marburg schist and associated quartzites and conglomerates.

AREA NORTH OF MARTIC OVERTHRUST

PIGEON HILLS ANTICLINORIUM

The Pigeon Hills fold is compound and consists of two large anticlines—a main one lying to the northwest, and a smaller one, with two still smaller anticlinal folds on its south flank, lying to the southeast. (See pl. 17.) The anticlinorium is cut by several transverse faults, which are of later date and offset the anticlines. The faults will be described under Triassic structure.

HIGH ROCK ANTICLINE

The main uplift, called the High Rock anticline, exposes a core of pre-Cambrian metabasalt (greenstone) in an area 5 miles long, extending from the western edge of the Hanover quadrangle to a point east of Maple Grove School. The fold plunges both to the southwest and to the northeast, and the Cambrian quartzites surround each end. The southwest end of the fold extends 1½ miles west into the adjacent Gettysburg quadrangle, where it is abruptly terminated by the plunge of the fold and normal faults with downthrow to the west. At the northeast end, the anticline divides into two arms. The northern arm is largely concealed by the overlapping Triassic rocks and its east end is terminated abruptly southeast of Farmers by normal faults with downthrow to the east. The southern arm pitches eastward and terminates near Roth Church in the symmetrical arc of Antietam quartzite which dips beneath the Vintage dolomite of the lowland. The shale at the base of the Kinzers formation, which overlies the Vintage dolomite, makes a parallel curved hill 1 mile farther out in the valley; and the upper sandstone of the Kinzers, an outer curved hill. A longitudinal fault near the middle of the fold has downthrow to the south so that the Lower Cambrian section is not complete on the south limb. The fold is covered on its north side by Triassic rocks which overlap onto the pre-Cambrian rocks.

GNATSTOWN ANTICLINE AND OVERTHRUST

The axis of the second anticline in the anticlinorium passes through Gnatstown and, therefore, is called the Gnatstown anticline. (See pl. 17.) It is broken on its north side by a thrust fault, called the Gnatstown overthrust, and overrides the High Rock anticline to the north. The basal conglomerate of the Hellam member and the underlying metabasalt are brought up in the core of this anticline along the Gnatstown overthrust 1 mile southwest of High Rock and probably also at Gnatstown; but the metabasalt, if present, is hidden by quartzite talus. Springs along this fault southwest of High Rock are the source of the Hanover water supply. Members of the Chickies quartzite and the Harpers phyllite appear in normal sequence on the south limb of the western part of the anticline. Higher beds are cut out by a longitudinal fault along the south side of the fold. Northeast of the Iron Ridge cross fault, which is described later, Cambrian rocks, from the Hellam conglomerate member of the Chickies quartzite to the Harpers phyllite, are exposed in a nearly symmetrical northeastward-pitching fold, broken on its north limb by the Gnatstown overthrust. Northeastward the fold bifurcates, and the Chickies quartzite in the northern arm extends more than a mile beyond its southern arm. The Antietam quartzite on the south limb of this part of the anticline extends 1½ miles northeast of Nashville, where it is terminated by the Gnatstown overthrust. Northeastward the overthrust cuts across the Vintage dolomite and the Kinzers formation on the south limb of the anticline. The northeasterly extension of the Gnatstown overthrust is described later.

ANTICLINES SOUTH OF THE PIGEON HILLS

South of the Gnatstown anticline, three short anticlines, each with a core of Harpers phyllite, are surrounded by the Antietam quartzite. These are the Menges Mills anticline, a nearly complete fold, which plunges both northeastward and southwestward; the Ambau anticline, another nearly complete fold, which plunges northeastward, is cut off at the west by the Iron Ridge cross fault, and is overridden on the southeast side by the Stoner overthrust; and the Mt. Carmel School anticline west of the Iron Ridge cross fault, a double fold, which plunges southwestward and may represent the two anticlines east of the cross fault. Anticlinal hills of Antietam quartzite northeast of the end of the Menges Mills anticline represent another uplift along that same general axis. The short eastward trending shale hill north of Nashville is composed of the lower member of the Kinzers formation on the north flank of the Menges Mills anticline. A longitudinal fault along the northwest side of Menges Mills anticline cuts off abruptly the west end of this shale hill at Nashville; and the east end is similarly truncated by another longitudinal fault. These longitudinal faults are younger and are described more fully under Triassic structure.

Three small linear hills of Antietam quartzite in the limestone lowland east of Nashville represent another uplift on the general axis of the Menges Mills anticline. These low hills, with deep-red sandy soil derived from uppermost beds of the Antietam quartzite, stand out prominently in the limestone lowland. The southeast sides of the hills are cut off abruptly by a fault that has dropped the limestone of the middle member of the Kinzers to the level of the Antietam quartzite. An iron ore pit lies on this fault.

SPRENKEL SCHOOL ANTICLINE

An anticline marked by a belt of hills composed largely of Kinzers formation extends from Spring Grove northeastward for 6 miles and is called the Sprenkel School anticline. It divides the limestone area of the valley southwest of York longitudinally into two narrow lowlands. Along the axis of the fold, Vintage dolomite comes to the surface at two places, one northeast of Spring Grove, and the other north of Sprenkel School. The lower shale member of the Kinzers formation, exposed in rows of low hills, entirely surrounds the dolomite; and the ends of the fold pitch steeply northeastward and southwestward. Along the Gnatstown overthrust, the Kinzers formation on the

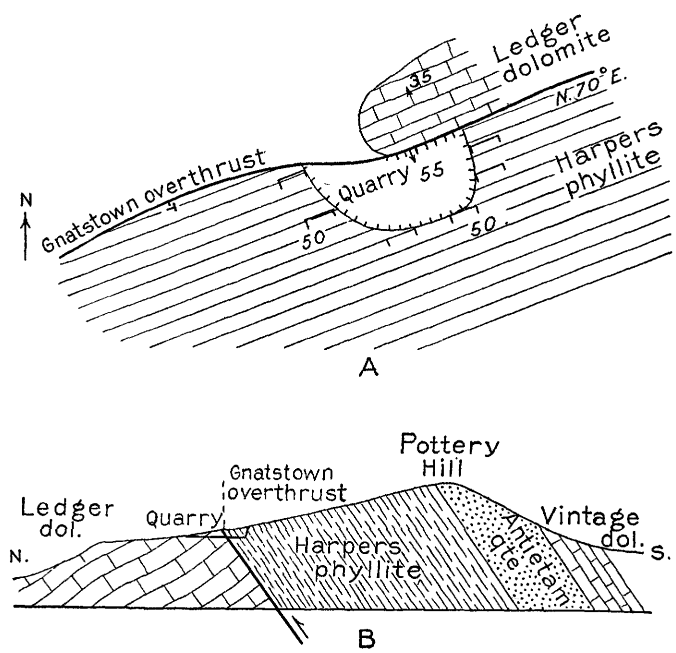


FIGURE 23.—Sketch of plan and section of the Gnatstown overthrust exposed in a small quarry along Lincoln Highway on Pottery Hill, southwest of York: A, Plan of the thrust fault, showing Harpers phyllite, with cleavage dipping 50° SE., overriding Ledger dolomite; B, Section across the fault.

north flank of the anticline overrides the Ledger dolomite and Conestoga limestone. South of West York, the small Pottery Hill anticline lies north of the east end of the Sprenkel School anticline. The axis of the Pottery Hill anticline trends east; and Harpers phyllite in the core is surrounded by Antietam quartzite, with Vintage dolomite on the southeast flank. This anticline is cut off on its west and north sides by the Gnatstown overthrust. The thrust plane is exposed in a small quarry on the south side of Lincoln Highway (U. S. 30) where it crosses Pottery Hill 1 mile southwest of West York. In the quarry the thrust plane dips 55° SE., and Harpers phyllite is thrust on Ledger dolomite, which makes the lowland to the northwest. (See fig. 23 and pl. 18, *B*.) Northeastward the Gnatstown overthrust is not clearly traceable in the city of York, but a possible further extension of the fault is discussed in connection with the Mount Zion anticline.

MOUNT ZION ANTICLINE

The Mount Zion anticline is the southern fold of the Hellam anticlinorium, and is largely in the Middletown quadrangle, north of the Hanover-York district. As described in the report on the Middletown quadrangle,[23] the Hellam anticlinorium is composed of four anticlines named the Chickies Rock, Trout Run, Accomac, and Mount Zion. Another fold just west of the Accomac anticline is now recognized as the Dugan Run anticline. (See fig. 24.) West and south of the Trout Run anticline are the Emigsville and Dee Run synclines. (See pl. 17.)

The Mount Zion anticline pitches southwestward and only its westward-plunging end enters the York quadrangle. Pre-Cambrian metabasalt is exposed in the core of the anticline northwest of Hellam in the Middletown quadrangle. Metabasalt and associated aporhyolite are exposed in the core of the Accomac anticline southwest of Accomac; and on the highway just south, metabasalt is closely folded, and the minor folds are overturned to the northwest. Along the south bank of the Susquehanna River west of Accomac (see fig. 24), aporhyolite and the Hellam conglomerate member of the Chickies

[23] Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pa.: U. S. Geol. Survey Bull. 840, pp. 50–53, 1933.

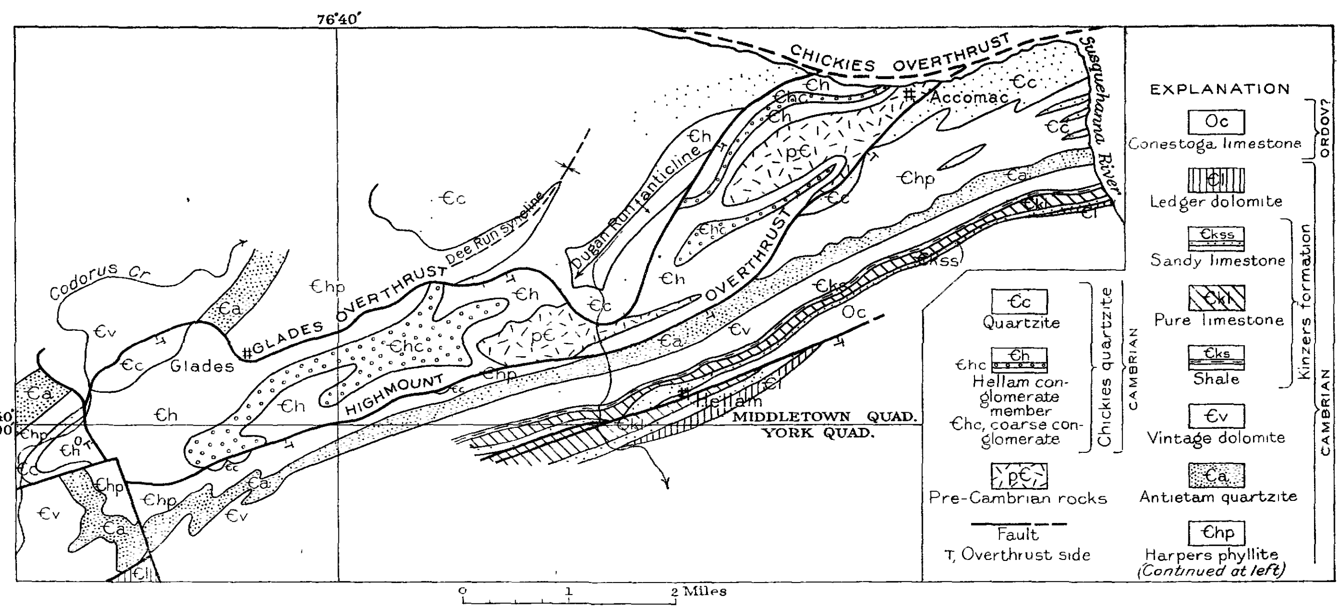


FIGURE 24.—Revised geologic map of the Mount Zion and Accomac anticlines in the Middletown quadrangle, showing the Glades and Highmount overthrusts. Specimen of mylonite from the Highmount fault, illustrated in plate 18, *A*, was obtained just east of Accomac.

quartzite on the north limb of the Accomac anticline are overturned and dip 35° SE. These rocks are much sheared in the vicinity of the Glades overthrust on the northwest side of the fold.

GLADES OVERTHRUST

The Accomac and Mount Zion anticlines override the Dugan Run anticline along the Glades overthrust. This thrust relationship is well shown in the stream gorge 1½ miles northwest of Hellam. (See fig. 24.) In an embayment in the front of the overthrust at this point, pre-Cambrian metabasalt and basal beds of the Hellam conglomerate member of the Chickies quartzite cut off and lap around the severed ends of Chickies quartzite beds in the Dugan Run anticline. Details of the structure here are shown in figure 24.

In the vicinity of Glades, upper beds of the Hellam conglomerate member are thrust across the Harpers phyllite and Antietam quartzite; and 1 mile west of Glades, the Chickies quartzite is thrust over Vintage dolomite. At Codorus Creek the Glades overthrust is overridden apparently by the Highmount overthrust. The rocks are well exposed in a small ravine just west of Pleasureville. (See fig. 4.) On the north side of the ravine, massive Chickies quartzite forms a rocky hill in which the beds strike southwestward toward the limestone in the lowland northwest of the fault; and south of the ravine, the upper slate and quartzite of the Hellam member strike parallel with the massive Chickies quartzite. Near the overthrust the hard beds of the thrust block are broken and veined with quartz, and the slaty layers are closely folded.

HIGHMOUNT OVERTHRUST

The southeast side of the Accomac and Mount Zion anticlinal block is bounded by a slightly curved fault trace. On the south side of the Mount Zion anticline, the Harpers phyllite on the south is in fault contact with various beds of the Hellam conglomerate to the north. From the evidence at hand in 1933 [24] the fault was considered to be a normal tension fault downthrown to the south and was called the Highmount fault. However, in two places near the north edge of the York quadrangle and at a point north of Stonybrook in the Middletown quadrangle, small masses of crushed, veined, and sheared Chickies quartzite lie next to the phyllite at the fault contact. Southeastward-dipping planes of schistosity are strongly developed in the phyllite and the quartzite at these places, and bedding is not evident. Northeastward in the Middletown quadrangle the fault separates basal beds of the Hellam conglomerate member and underlying pre-Cambrian metabasalt in the core of the Mount Zion anticline from the Harpers phyllite on the south. Northwest of Hellam the Harpers phyllite south of the fault is cut out, and Antietam quartzite is at the contact. In the closely folded Antietam quartzite near the fault the bedding planes have been largely transposed to the direction of the cleavage, which dips 45° SE. Beyond this point the fault bends sharply northward across the structure, and at Highmount crushed and veined Chickies quartzite is in contact with gently dipping basal beds of the Hellam member and underlying metabasalt in the core of the Mount Zion anticline. The fault contact is exposed in a small ravine just south of Accomac. (See fig. 24.) Here finely laminated gray slate with thin quartzite layers, belonging to the upper part of the Chickies quartzite, is in contact with and overlies schistose metabasalt in which the cleavage dips 45° SE. The quartzose banded slate is minutely folded and mylonitized (see pl. 18, *A*); and the cleavage, parallel to the axial planes of the folds, dips 45° SE. The metabasalt at the fault contact is also sheared to a schistose mylonite. The fault plane, accompanied by a quartz vein near the contact, dips 45° SE.

The preceding evidence indicates that the Highmount fault is not a normal tension fault but is a thrust fault that was formed under compression. The southeastward dipping cleavage, brecciation, and veining of the rocks of the southeast side of the fault, and the less disturbed condition of the Hellam conglomerate northwest of the fault suggest that the rocks to the southeast were thrust northwestward along a fault that dips 45° SE., as shown in the exposure near Accomac.

The Hellam Hills uplift, which in earlier studies appeared to be a single anticline with an overthrust fault on its northwest side and uplifted on its south side along a normal tension fault, is in reality two anticlines and an intervening syncline, the southern anticline having been thrust northward and superimposed on the northern one. The diagrammatic map (fig. 25) shows the postulated folds before faulting. The north limb of the northern fold, the Mount Zion anticline, was strongly overturned and broken, and the anticline was pushed northwestward along the low-dipping Glades overthrust, which cuts diagonally across the beds from the pre-Cambrian rocks in the core of the fold northwest of Hellam to the Chickies quartzite at the westward-plunging end of the fold at the Codorus gorge. The southern fold, the Chickies Rock anticline, was broken by the Highmount overthrust, which cuts out much of the north limb of the fold, so that south-dipping beds of the south limb were thrust northwest over the intervening syncline and came to rest on the south flank and the core of the Mount Zion anticline. Younger rocks were thus thrust over older rocks. The Highmount fault is steeper, and consequently its trace is straighter than that of the Glades overthrust. Toward the east the fault cuts diagonally across the structure to the north side of the anticline in Roundtop and Chickies Rock.

[24] Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pa.: U. S. Geol. Survey Bull. 840, pl. 1, 1933.

At the westward-plunging end of the Chickies Rock anticline, north of York, the Highmount fault apparently breaks across the axis of the fold, and cuts upward through the Harpers phyllite, Antietam quartzite, and Vintage dolomite into the Kinzers formation on the north limb of the anticline at Myers Mill. (See fig. 25.) The Kinzers formation south of Emigsville (see fig. 24) dips 10° S. and is greatly overturned, and the limestone of the middle member of the Kinzers formation is thrust over the Vintage dolomite in the Emigsville syncline. West of Pleasureville the Highmount thrust mass overrides the end of the Glades thrust block and extends beyond onto the Vintage dolomite. (See fig. 4). In the northern part of York the shale on Prospect Cemetery Hill and on the hill to the east is the basal member of the Kinzers formation at the plunging end of the Chickies Rock anticline, and the interrupted exposures are due to fragmentation of the fault block during overthrusting. Likewise the irregularly distributed masses of limestone, together with fragments of the lower shale and upper sandstone members of the Kinzers formation, which are surrounded by Ledger dolomite west of York (see pl. 1), are apparently erosion remnants of the Highmount overthrust block resting as klippen on the Ledger dolomite of the overridden block. Confirming this interpretation, in most

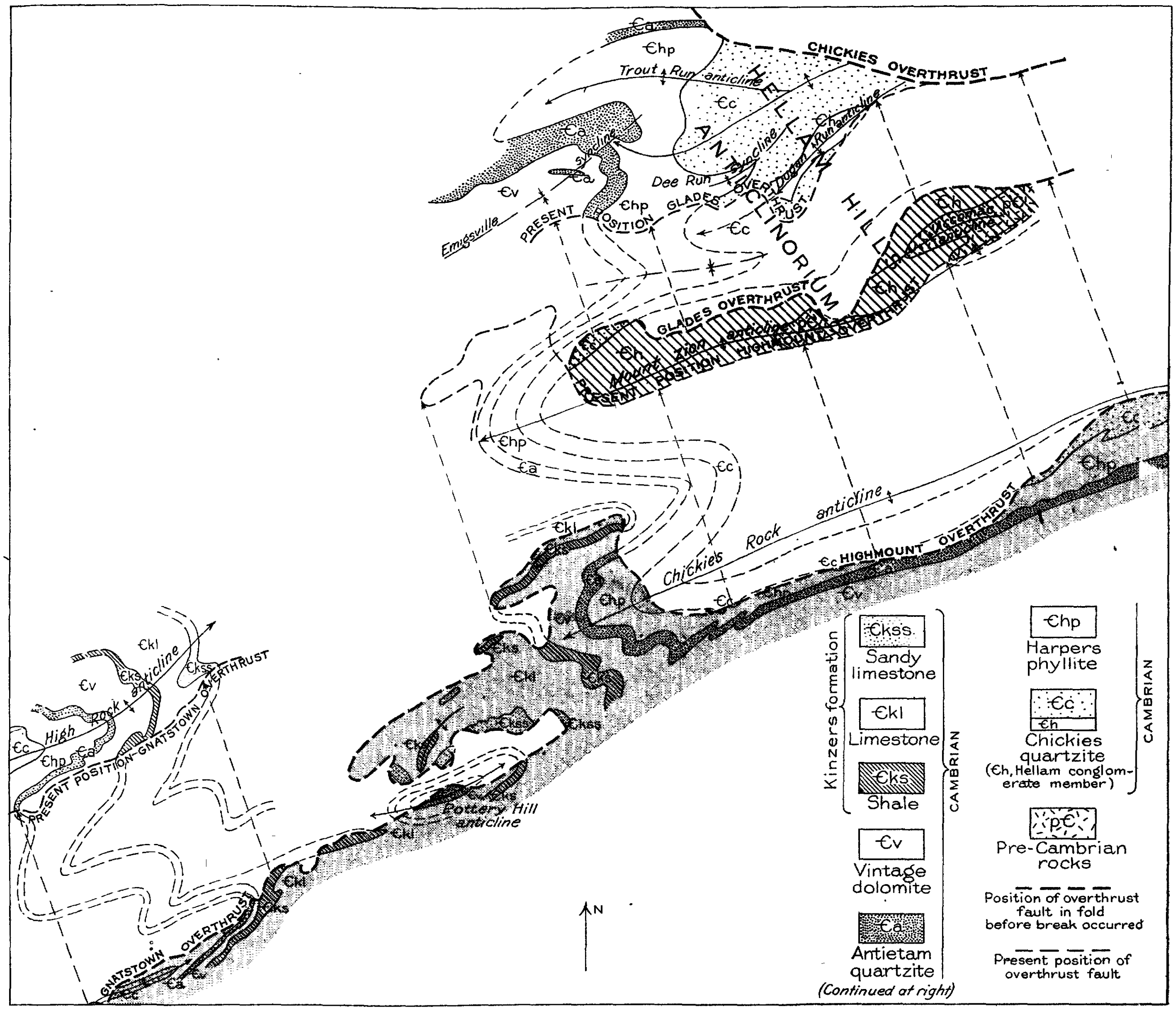


FIGURE 25.—Theoretical restoration of folds of the Hellam Hills anticlinorium before they were broken and overthrust. Original position of the Glades thrust block on north limb of the Mount Zion and Accomac anticlines and its present position overriding the Dugan Run anticline to the north are shown. Exposed part of the Glades thrust block is indicated by ruled pattern. Original position of the Highmount thrust block on the south side of the Chickies Rock anticline and its present position covering most of the Chickies Rock anticline and overriding west end of the Mount Zion anticline are indicated. Probable connection of the Highmount and Gnatstown overthrusts, including klippen of Kinzers formation northwest of York, is suggested. Northwest edge of the Gnatstown-Highmount thrust block is indicated by halftone pattern. Present position of the Gnatstown overthrust block on south limb of the High Rock anticline in the Pigeon Hills is shown at left. Amount of movement on overthrusts is not known.

places the rocks of the Kinzers formation in these remnants are closely folded and contorted, whereas the Ledger dolomite of the overridden block is only gently folded.

If this is the correct interpretation of the structure, the Highmount fault was once continuous around these detached masses from the Kinzers formation and joined the Gnatstown overthrust exposed on the north side of the Pottery Hill anticline. (See fig. 25.) Block faulting in the thin overthrust plate and later erosion, however, make it difficult or impossible to trace these faults into one another.

RELATION OF THE PIGEON HILLS, HELLAM HILLS, AND BLUE RIDGE-CATOCTIN MOUNTAIN ANTICLINORIA

The Pigeon Hills and Hellam Hills anticlinoria (fig. 26) are evidently local uplifts along the same general axis. In the Middletown quadrangle the Hellam Hills fold is broken on the north side by the Chickies overthrust,[24] along which Lower Cambrian quartzites have moved over the limestones of the Marietta valley. The overthrust is covered by the overlapping Triassic rocks south of Mount Wolf in the Middletown quadrangle. The Pigeon Hills anticlinorium similarly is believed to be overthrust on its north side; for, if resistant Cambrian quartzites were present on the north limb of the fold during Triassic deposition, hills equal in height to the main Pigeon Hills should occupy the area, instead of the depression that forms the floor of the adjacent Triassic rocks. The Triassic rocks in this area probably lie mostly on limestone and cover the postulated thrust fault that may be the southwesterly extension of the Chickies overthrust along the original northwest base of the Pigeon Hills.

In the Fairfield, Pa., quadrangle [25] and the Emmitsburg, Md., quadrangle west and southwest of this district, a broad anticline of pre-Cambrian volcanic rocks flanked on both sides by Lower Cambrian quartzites forms the Blue Ridge-Catoctin Mountain anticlinorium. A branch of this fold trends northeastward toward the Pigeon Hills anticlinorium, but is terminated abruptly by the normal fault, which crosses the trend of the pre-Triassic structures, along the west side of the Triassic basin. Although these two anticlines are separated by a belt of Triassic rocks about 25 miles wide, they lie probably on the same general axis of uplift and were separated by the downwarping of the Triassic basin and by post-Triassic normal faulting along the western border of the Triassic sediments. (See fig. 26.)

WRIGHTSVILLE SYNCLINE

The Wrightsville syncline occupies the Hanover-York Valley underlain mainly by limestone. (See pl. 17.) East of York Conestoga limestone is generally at the surface. Northeast of York, on the north side of the syncline, the Lower Cambrian limestone formations dip south from the Mount Zion anticline and pass beneath the Conestoga limestone, which also dips southward. On the south limb of the syncline these Cambrian formations rise from beneath the Conestoga limestone but still dip southward because the beds are overturned. South of Wrightsville at the Susquehanna River, the Lower Cambrian formations on the north limb of the Strickler anticline emerge from beneath the Stoner overthrust and are likewise overturned and dip southward.

In the southern part of York near the center of the syncline, the Conestoga limestone is well exposed in brick yards where the disintegrated rock and soil have been stripped from the bedrock. The thin-bedded limestone is closely folded, and the axial planes of the folds dip uniformly south. The beds on the limbs of the folds have been thinned and the crests and troughs thickened by the differential movement of material. (See fig. 19.) Southwest of York, the Conestoga limestone has been uplifted in minor anticlines and eroded locally; but it continues southwestward to a point south of Bair, beyond which Ledger dolomite is exposed at the surface in the syncline. The part of the syncline exposed north of the Stoner overthrust at Spring Grove is very narrow. To the southwest the syncline is further constricted by the Ambau anticline, and is terminated by the uplift along the Iron Ridge cross fault. The Hanover Valley is another broad syncline along the same general strike, and incloses tightly folded Conestoga limestone. The folds are probably also overturned to the north, but exposures in this lowland are few and poor.

STRICKLER ANTICLINE

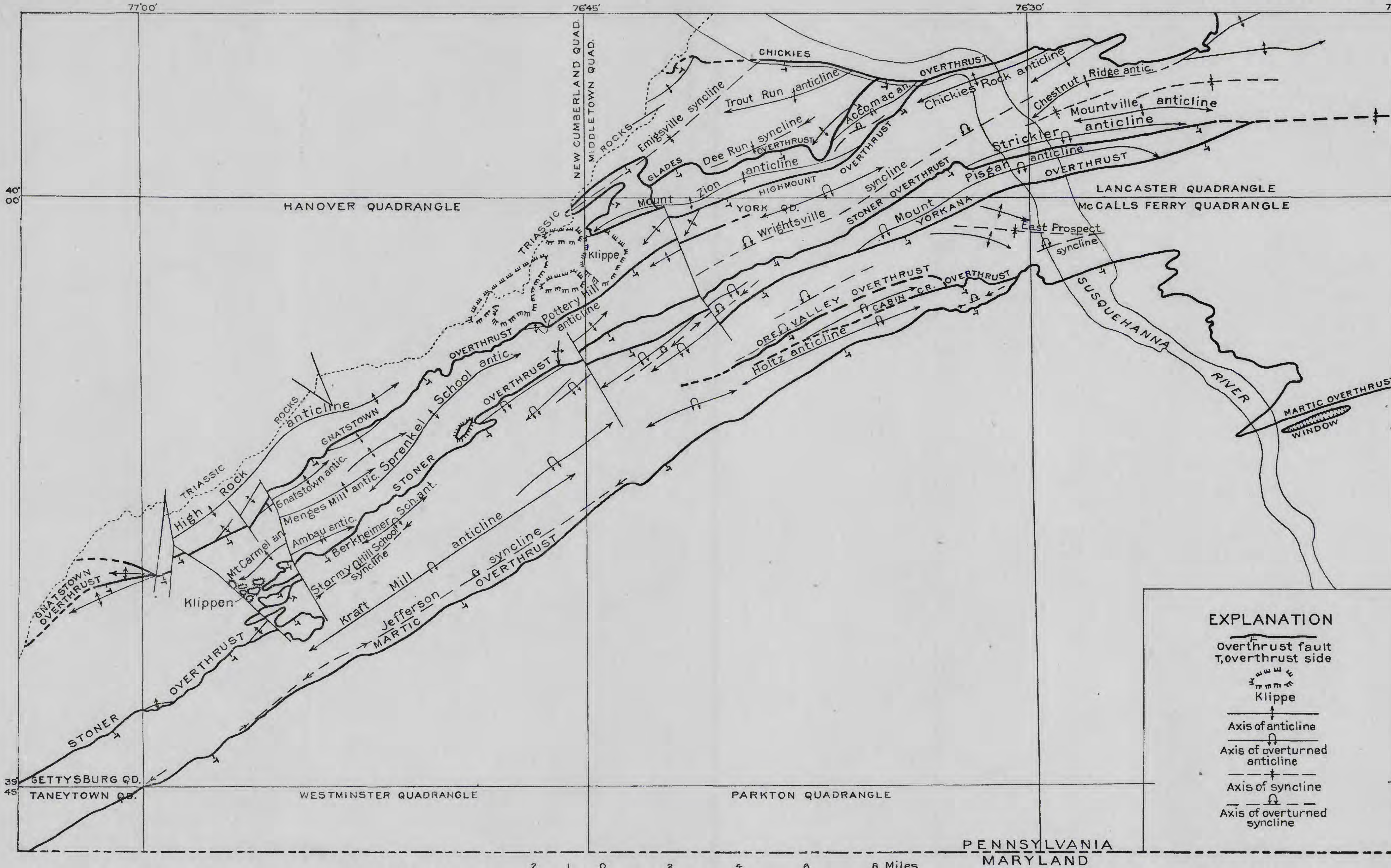
The Strickler anticline lies south of the Wrightsville syncline. (See pl. 17.) In the southeast corner of the Middletown quadrangle, the anticline is well exposed in the west bank of Susquehanna River. Antietam quartzite forms the core of the anticline, and Vintage dolomite and the lower shale member of the Kinzers formation lie on the flanks. The anticline is largely concealed in the Hanover-York area by the Stoner overthrust. The Lower Cambrian formations on the north limb of the anticline are exposed along the south side of the valley from Plank Road northeast to the edge of the York quadrangle.

STONER OVERTHRUST

The Stoner overthrust follows the northwest edge of the wide area of the Lower Cambrian quartzose rocks, exposed south of the Hanover-York Valley, from a point near Stoner Station, at the north edge of the York quadrangle, southwestward to the vicinty of Hanover. (See pl. 17.) The overthrust has not been

[24] Stose, G. W., and Jonas, A. I., Geology and Mineral resources of the Middletown quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 840, pp. 51, 54–56, 1933.

[25] Stose, G. W., Fairfield-Gettysburg folio: U. S. Geol. Survey, Geol. Atlas (no. 225), Fairfield geologic map, 1929.



MAP OF THE HANOVER-YORK DISTRICT AND ADJACENT REGION, SHOWING MAJOR STRUCTURAL AXES AND THRUST FAULTS NORTH OF THE MARTIC OVERTHRUST.

Normal faults, except the larger transverse ones that offset the thrusts, are omitted. Structure lines south of Martic overthrust are shown in figure 27.

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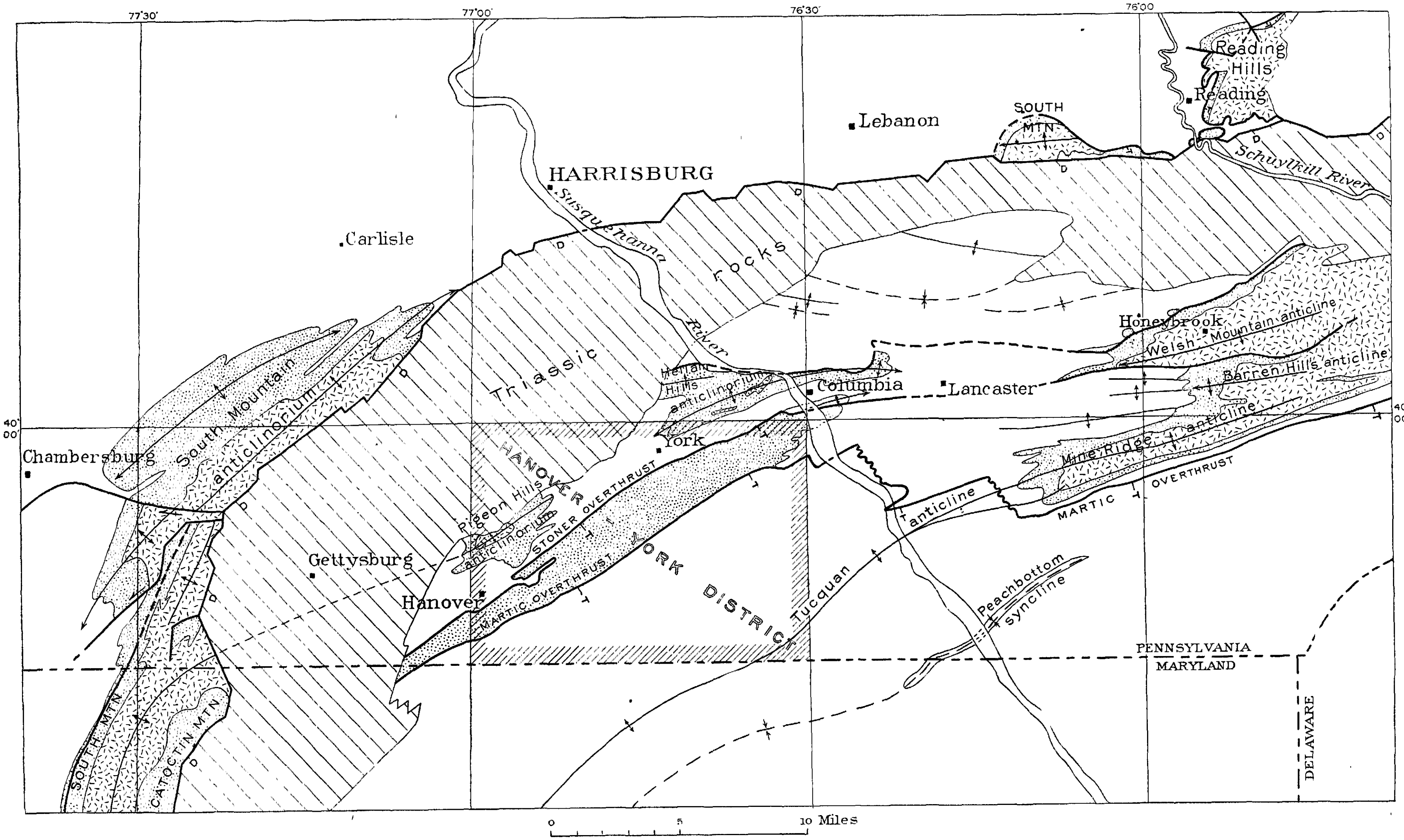


FIGURE 26.—Map of southeastern Pennsylvania and adjacent part of Maryland, showing relationship of general structure in the Hanover-York district to major structural features of region. Many faults are omitted. T, overthrust side of thrust fault; D, downthrown side of normal fault. Quartzose and argillaceous Lower Cambrian formations, dotted; pre-Cambrian rocks in cores of anticlines, dash pattern. The Pigeon Hills and Hellam Hills anticlines are apparently the easterly continuation of the South Mountain-Catoctin Mountain anticline in Maryland, and trend toward the Welsh Mountain anticline. The Tucquan anticline is the western continuation of the Mine Ridge anticline.

actually observed, but structural evidence of its presence is convincing throughout most of its course. The overthrust nature of this contact is not clearly indicated in places where the Conestoga limestone lies next to the fault, because the relationship between the Conestoga and the adjacent Harpers phyllite or Chickies slate may be mistaken for the unconformable overlap that elsewhere is known at the base of the Conestoga limestone. From Plank Road northeastward for 6 miles, however, a narrow band of Kinzers formation, Vintage dolomite, and Antietam quartzite emerges from beneath the Conestoga limestone on the southeast limb of the Wrightsville syncline; and the overthrust is evident. Northeast of the district, in the Middletown quadrangle,[26] the overthrust is better demonstrated, for the Stoner overthrust swings southeastward across the structural trend and reveals the Strickler anticline, as shown in plate 17. East of Susquehanna River the Manor anticline, which is the northeastern extension of the Mount Pisgah anticline, is thrust over the Strickler anticline along the Stoner overthrust. Still farther eastward, the Stoner overthrust is lost to sight in the Conestoga limestone south of Lancaster. At Plank Road and south of West York, the Stoner overthrust is offset by cross faults.

West of York New Salem a recess in the fault front is the result of erosion of the thin overthrust mass; and a klippe or outlier composed of Harpers phyllite forms a hill that rises above the limestone lowland in the embayment. Southwest of Lehman, the Harpers phyllite is thrust over the southeast limb of the Ambau anticline and cuts across the beds down to the Antietam quartzite. The thinness of the overthrust plate is shown by the deep recesses in the fault front and the klippen of Harpers phyllite on the limestone lowland west and south of Jacobs Mills.

At Jacobs Mills the overthrust swings around the end of a narrow hill of Harpers phyllite and extends 1 mile northeastward up a narrow valley in which Vintage dolomite and Antietam quartzite of the overridden block are exposed. Southeast of Jacobs Mills, a split in the fault encloses a southward-dipping monoclinal slice with Kinzers formation at the top. One mile southwest of Jacobs Mills overthrust Harpers phyllite forms a similar promontory, south of which the overthrust swings eastward for 2 miles around the limestone lowland at Penn Grove, a deep irregular embayment in the overthrust front. South of Hanover the Harpers phyllite is thrust over an anticline in which are exposed Antietam quartzite, Vintage dolomite, and the lower shale member of the Kinzers formation. The overthrust is cut and offset by the Iron Ridge and the Smiths Station cross faults.

[26] Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pa.: U. S. Geol. Surv. Bull. 840, pp. 53–54, 1933.

All the rocks of the Stoner overthrust block are closely folded, and the axial planes of the folds dip southeastward. At several places the rocks of the thrust block and the rocks they override have been seen in the same outcrop, but the contact was hidden. In the cut on the Pennsylvania Railroad east of the highway to Brillhart, the Harpers phyllite on the front of the Stoner overthrust is closely folded, and the folds are in part sheared out. The most evident structure is a wavy foliation that dips 45° SE. Imperfectly developed transverse cleavage cuts the foliation at a steeper angle. Farther southeast, quartzose beds in the Harpers phyllite and the underlying Chickies slate are closely folded and the folds are overturned northwestward. (See figs. 6, 7.) Structure is similar at the edge of the overthrust mass south of Plank Road. There, Harpers phyllite is thrust over a syncline of Vintage dolomite and Antietam quartzite and only 50 feet of the Antietam is exposed next to the fault in the cut of the Maryland and Pennsylvania Railroad. The beds of the Antietam and the Vintage are vertical.

The sinuous outline of the Stoner overthrust southwest of York, especially north of Smiths Station, and the small outliers that rest on Vintage dolomite west of Jacobs Mill, indicate a low angle of dip for the thrust plane, which was gently folded during or after thrusting. The Harpers phyllite in that area does not show bedding, but has a closely folded laminated structure with a transverse cleavage, which in places is crinkled. In the valley, rocks of the underlying block near the thrust are closely folded and overturned northwestward, and cleavage is developed in the weaker strata and in some of the harder beds.

The Stoner overthrust block is about three miles wide. It is overridden on the southeast side by the Martic overthrust block. In the York area the Stoner block comprises the Mount Pisgah and Holtz anticlines and the intervening East Prospect syncline; in the Hanover area it includes the Berkheimer School anticline, the Stormy Hill School syncline, the Kraft Mill anticline, and the Jefferson syncline.

MOUNT PISGAH ANTICLINE

The Mount Pisgah anticline is a narrow fold that extends from the northeastern edge of the area southwestward to York New Salem. (See pl. 17.) The anticline is closely folded; and the beds dip steeply and are for the most part overturned to the northwest, especially along the edge of the Stoner overthrust. The repetition of beds by folding is well shown in the valleys of Kreutz and Mill Creeks east of York and in the cliff east of Codorus Creek, below the York Country Club. On the highest part of the anticline, northeast of York, the basal Hellam conglomerate member of the Chickies slate is exposed in a strip 5 miles long. The Chickies slate is exposed as far southwest as York New Salem and is brought up again southwest of Stovertown in the Berkheimer School anticline, which is on the same axis of uplift as the Mount Pisgah anticline. In the quartzite beds of the Chickies slate, anticlinal folds whose axial planes dip 30° to 45° southeast are exposed northeast of York New Salem and on the grounds of the York Country Club on the east side of East Branch of Codorus Creek. (See fig. 7.)

KRAFT MILL ANTICLINE

The Kraft Mill anticline lies to the south of the Berkheimer School anticline in the Hanover quadrangle (see pl. 17), and brings up a wide belt of Chickies slate, which extends from a point near Reynolds Mill southwestward nearly to Hohf School. In the Kraft Mill anticline and also in the Mount Pisgah anticline, the folds are overturned to the northwest; and both the bedding and the cleavage dip mostly southeast. The close folding is exposed in the valleys east of York New Salem and along Codorus Creek south of Porters Station.

The Chickies slate in the Stoner overthrust block is a different lithologic facies of the Chickies quartzite in the anticlines north of the Hanover-York Valley. Overthrusting has brought the slate nearer the quartzose facies, but the amount of movement is not known. If, as is possible, the Stoner overthrust dies out in the limestones east of the Manor anticline, west of Lancaster, the amount of movement appears not to have been great; however, the Mount Pisgah anticline, which contains the slaty facies of the Chickies, lies 12 or 15 miles northwest of the trend of Mine Ridge anticline, which contains a quartzite facies similar to that in the Hellam Hills. If the basin of deposition of the slaty facies originally lay southeast of the basin in which the quartzite facies was deposited, that is, south of the trend of Mine Ridge anticline, the slaty facies in the Stoner overthrust has moved northwestward at least 15 miles. The writers believe that the Glenarm series was carried a great distance northwestward on the Martic overthrust and that the Stoner overthrust block, which lies north of the Glenarm series, may have been pushed up in front of the advancing Martic overthrust.

EAST PROSPECT SYNCLINE

The East Prospect syncline lies south of the Mount Pisgah anticline in the York quadrangle, and encloses Antietam quartzite and overlying limestone. (See pl. 17.) The fold deepens to the east, where it merges with the Lancaster syncline to form a wide valley in the limestone. The limestones are enclosed in three synclinal folds, two north of and one south of East Prospect. The two northern arms, enclosing Kinzers formation and Vintage dolomite above the Antietam quartzite, are in the valleys of Canadochly Creek and the small stream at Klein School. The southern arm is overridden on the south by the Cabin Creek overthrust, which splits off from the Martic overthrust. One mile west of Margaretta Furnace the limestone in the syncline is cut off by the Ore Valley overthrust, a split of the Cabin Creek overthrust. The Harpers phyllite on the Ore Valley fault overrides Antietam quartzite to a point north of Spry, except at Ore Valley where a narrow strip of limestone, probably Conestoga, is enclosed in a syncline next to the fault. Two other shallow synclines of limestone occur in the Antietam quartzite, one south of Delroy and the other along Kreutz Creek south of Golden. The one near Delroy is in strike with the Ore Valley syncline.

South of Margaretta Furnace, another syncline encloses Antietam quartzite, a thin band of Vintage dolomite, and Conestoga limestone. This syncline lies south of the strike of the Holtz anticline, and is cut off on the south side by the Martic overthrust.

JEFFERSON SYNCLINE

The Jefferson syncline, which encloses Antietam quartzite and Conestoga limestone, is south of the Kraft Mill anticline and extends from a point 2 miles southwest of Jacobus southwestward to Sinsheim. (See pl. 17.) This syncline lies south of the trend of the Holtz anticline and may be the southwesterly extension of the southernmost fold in the East Prospect syncline. A mile southwest of Sinsheim, another downfold along the axis of this syncline encloses the Antietam quartzite and Conestoga limestone in an area about three miles long. The main part of the syncline is double and contains two narrow bands of Conestoga limestone separated by an anticline of Antietam quartzite. At one point on the north side of the syncline, northwest of Seven Valleys, a small area of Vintage dolomite is exposed between the Conestoga limestone and the Antietam quartzite. The Jefferson syncline is overridden on the south side by the Marburg schist along the Martic overthrust. At the western edge of the Hanover quadrangle a small area of Antietam quartzite is enclosed along this same synclinal axis and lies just north of the Martic overthrust.

HOLTZ ANTICLINE

The Holtz anticline is a narrow, closely compressed anticline which brings Chickies slate to the surface from a point 1½ miles west of Margaretta Furnace southwestward to East Branch of Codorus Creek. (See pl. 17.) The fold is compound and is composed of three minor folds, which plunge at their ends and which are arranged enéchelon. The axis of the main fold passes through Holtz. At the northeast end the axis of one minor parallel fold is half a mile to the north, and at the southwest end another minor fold lies south of Spry. The Cabin Creek overthrust carries the main fold over the northern one. In the area south of Margaretta Furnace the Antietam quartzite, Vintage dolomite, and

Conestoga limestone are enclosed in a syncline south of the main fold.

The folding in the Holtz anticline is very close, and the folds are sheared out by steeply dipping transverse cleavage. The argillaceous layers form a series of steeply dipping lenses parallel to the cleavage. The type of folding observed south and southwest of Margaretta Furnace is illustrated in plate 18, *C*. From Ore Valley south to Relay along the highway that follows Mill Creek, road cuts show the best and most continuous outcrops of the Chickies slate and overlying Harpers phyllite in the Holtz anticline. The fold axes in the quartzite dip steeply to the southwest. In the softer beds, where folds have been sheared out, nearly vertical lineation parallel to the fold axes shows on the cleavage planes. Vertical surfaces show the fold axes, and horizontal surfaces, the cross sections of rock layers. The pitch of the folds ranges from 80° SW. to vertical three-quarters of a mile southeast of Ore Valley, but is only 20° to 40° SW. at Relay. On the upland on either side of Mill Creek, lack of outcrops prevents tracing the strike of the beds or determining the extent of steeply dipping folds. This area exhibits on a small scale a steep fold-axis structure, which is widespread in Maryland.[27]

AGE OF THE STRUCTURAL FEATURES

The folding and the thrust faulting in the district involved all the Paleozoic rocks, the youngest of which are probably of Ordovician age. The magnitude of these folds and overthrusts and their general parallelism with those of the Great Valley lead to the conclusion that they were formed at the same time as the major folds and overthrusts throughout the Appalachian province. These structural features elsewhere affect the Carboniferous rocks and, hence, were produced during the mountain making epoch that occurred at the close of the Carboniferous period. Most of the transverse faults, which cut across and offset the folds and overthrusts in the Hanover-York district, are distinctly younger and are described under Triassic structure. In the Glades overthrust block north of York, certain transverse faults that do not pass into the overridden limestones were evidently formed during later Paleozoic thrusting and represent the fragmentation of the overthrust block.

MARTIC OVERTHRUST BLOCK

GENERAL DESCRIPTION

The Martic overthrust block occupies the southeastern part of the Hanover-York district, and is bounded on the northwest by the Martic overthrust. (See fig. 27.) It extends from Cabin Creek at the east edge of the district southwestward through Relay, Jacobus, Seven Valleys, Jefferson, and Sinsheim, and thence southwestward beyond Fairview School. It passes out of the district 1¼ miles north of Raubenstine, and continues southwestward across Maryland. In this thrust block, Marburg schist has been carried northwestward over the Conestoga limestone, the Antietam quartzite, and the Harpers phyllite of the Stoner block. The Martic overthrust is indicated on the map by a dashed fault line in localities where Marburg schist has been thrust over Harpers phyllite, because the Harpers phyllite somewhat resembles the Marburg schist, and the fault that separates them cannot be located exactly. Where the Martic overthrust enters the Hanover-York district from the east, the Marburg schist is thrust over the Conestoga limestone in the East Prospect syncline, and just to the west, over the Antietam quartzite and infolded Conestoga limestone in the Cabin Creek syncline. Three and a half miles from the east edge of the district, the Marburg schist overrides the Harpers phyllite on the south limb of the Holtz anticline; and this relation is maintained to a point 1½ miles west of Jacobus, where Antietam quartzite and Conestoga limestone in the Jefferson syncline lie north of the Martic overthrust. This syncline is adjacent to the fault in the Hanover quadrangle except southeast of Hanover, where Harpers phyllite is at the contact. At the west edge of the quadrangle the syncline north of the fault again encloses Antietam quartzite.

The main folds which can be recognized within the Martic overthrust block in the district are the Tucquan anticline and the Yoe and Wentz synclines. The Yoe syncline, southeast of York, is near the front of the overthrust block. The Wentz syncline parallels the Yoe syncline; but the Wentz axis, if extended, would pass southeast of the Yoe axis. Both synclines infold the quartzites associated with the Marburg schist. The Wissahickon formation, lying southeast of the Yoe and Wentz synclines, forms the largest part of the Martic overthrust block in the district. From a point near Brownton southwestward, the Wissahickon formation encloses narrow bands of metabasalt that probably were brought up on anticlines. Southwest of Glenville, Wakefield marble accompanies the metabasalt.

TUCQUAN ANTICLINE

The major structural feature in the southeastern part of the York quadrangle is the Tucquan anticline, which extends along South Branch of Muddy Creek and continues southwestward to the Maryland line near Deer Creek. The Martic overthrust block was first described in the report on the adjoining McCalls Ferry quadrangle.[28] In that area the Tucquan anticline, exposing

[27] Jonas, A. I., Tectonic studies in the crystalline schists of southeastern Pennsylvania and Maryland: Am. Jour. Sci., 5th ser., vol. 34, 1937.

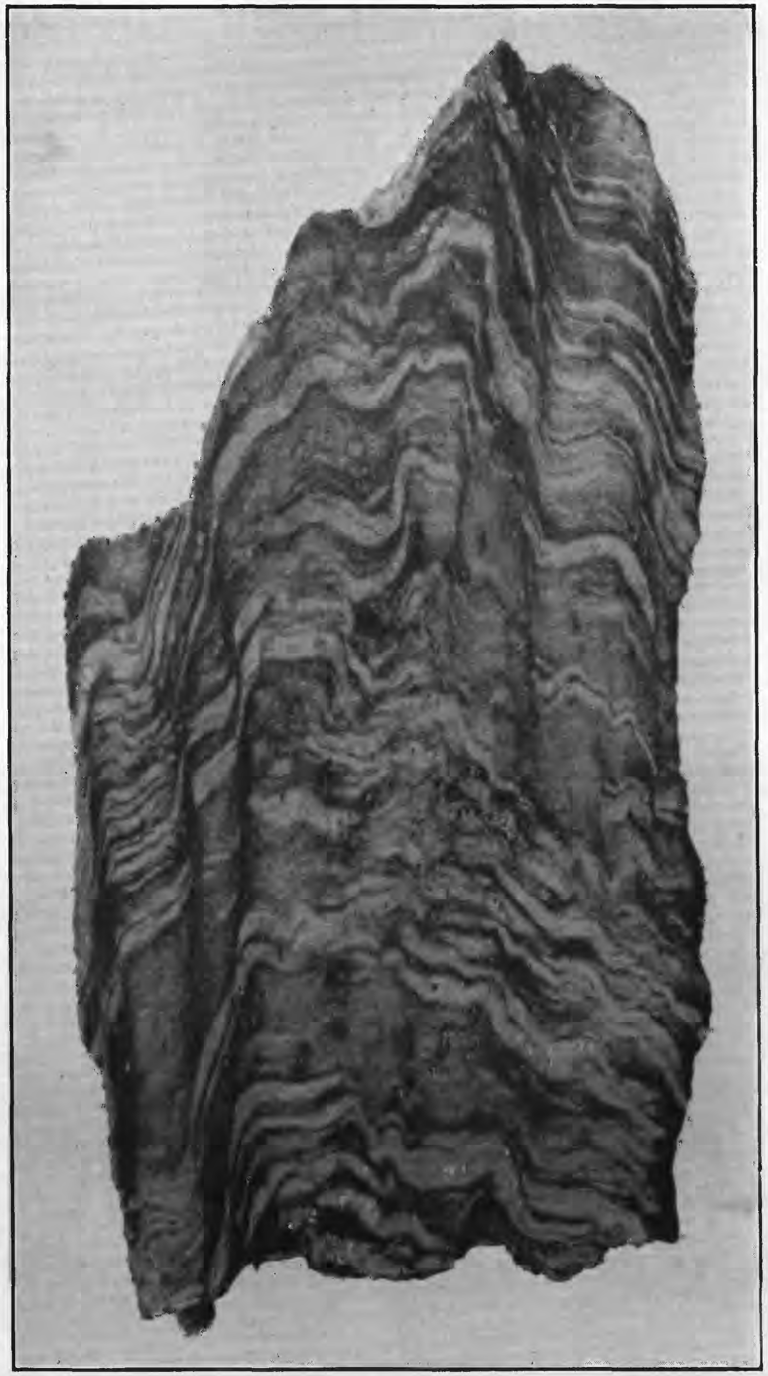
[28] Knopf, E. B., and Jonas, A. I., op. cit., U. S. Geol. Surv. Bull. 799, pp. 71–80, 1929.

A. MYLONITIZED CHICKIES QUARTZITE FROM SOLE OF HIGHMOUNT THRUST FAULT, HALF A MILE SOUTHWEST OF ACCOMAC.

Locality is shown on figure 24. Transverse cleavage (indicated on the photograph by the nearly vertical lines) dips 45° SE., parallel to the fault plane.

B. HARPERS PHYLLITE THRUST NORTHWESTWARD OVER LEDGER DOLOMITE AT LEFT, IN SMALL ROADSIDE QUARRY ON POTTERY HILL, SOUTHWEST OF YORK.

Exposed fault plane dips 55° SE.



C. POLISHED SURFACE OF CLOSELY FOLDED QUARTZOSE HARPERS PHYLLITE SOUTH OF MARGARETTA FURNACE.

Shows vertical cleavage. Natural size.

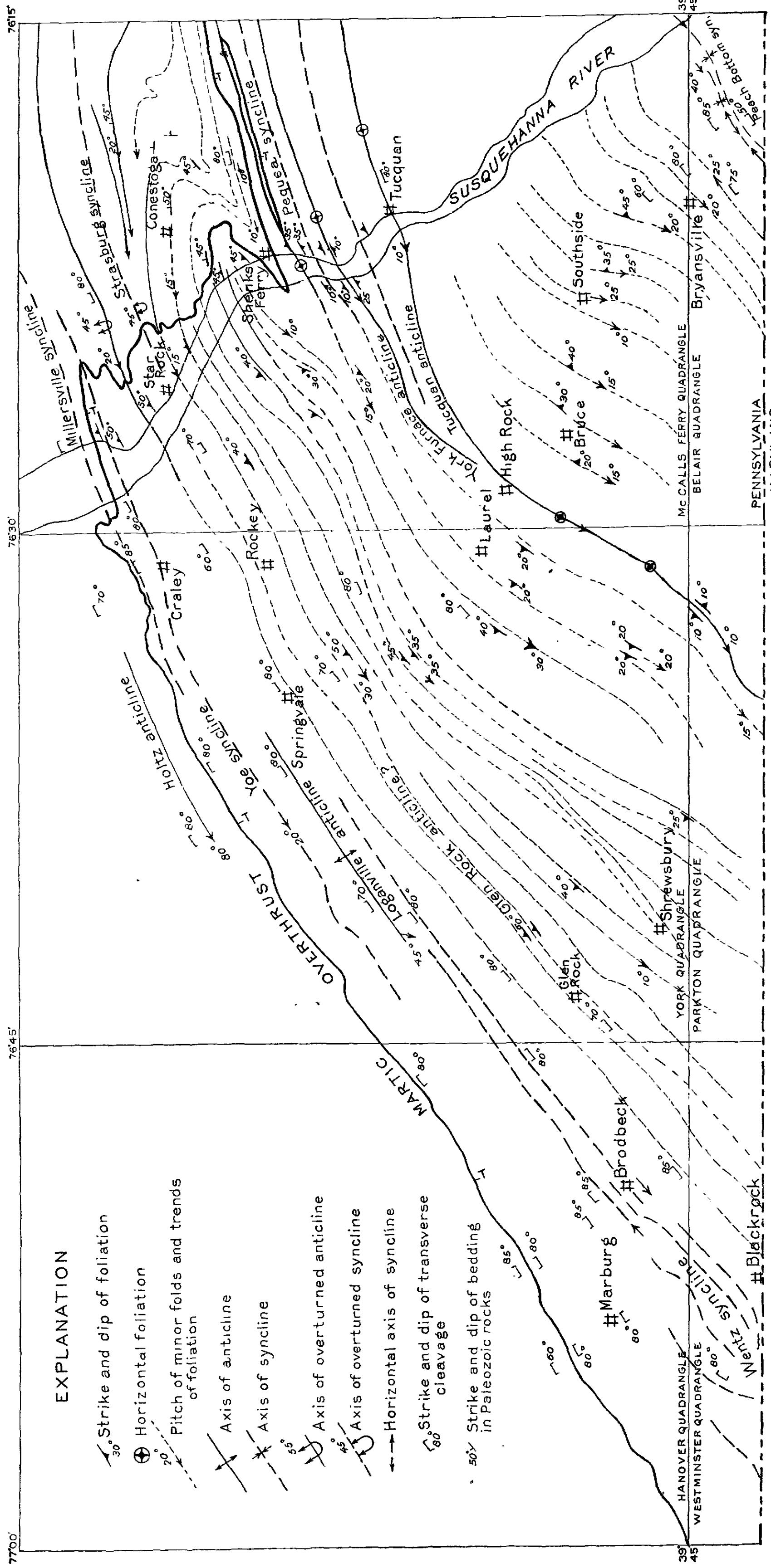


FIGURE 27.—Sketch map of the Hanover-York district and adjacent areas, showing structural axes and structure trends in the Martic thrust block and adjoining Paleozoic rocks.

the albite-chlorite schist facies of the Wissahickon formation, begins as a double arch two miles west of Quarryville and crosses the Quarryville and McCalls Ferry quadrangles to a point near High Rock, one mile east of the York quadrangle, from which a single broad arch continues southwestward. The compound fold is the southwesterly continuation of the double anticline of Mine Ridge (see figs. 26 and 27), which is developed in the pre-Cambrian and lower Paleozoic rocks of the overridden block. The Paleozoic rocks plunge southwestward from the nose of the Mine Ridge anticline; and the youngest formation, the Conestoga limestone, passes southwestward under the albite-chlorite schist, and the schists and Paleozoic rocks are folded together.

DETAILED STRUCTURE

In figure 27 the structural trends of the fold axes in the schists of the Martic overthrust block are based on observation of the trends of lineation, which parallel the tectonic axes.[29] If outcrops in the schists were more continuous, the trends of the fold axes could be determined more accurately. At the crest of the Tucquan anticline, the foliation and the axial planes of those recumbent folds that have escaped destruction are horizontal or gently inclined. The dips of the axial planes of the recumbent folds and of the foliation formed by the shearing out of the folds gradually steepen in opposite directions away from the crest of the anticline. (See fig. 27.) The foliation layers are folded into gentle folds whose axial planes also dip away from the crest. These foliation folds have a longer and a shorter limb. The longer limb always dips away from the crest, but the shorter limb in places dips towards it. In the section along North Branch of Muddy Creek, the foliation at Laurel, 1½ miles west of the crest of the arch, dips 20° NW.; at Felton the dip has increased to 45° NW.; and northwest of Brownton it is 50° NW. The fold axes of the foliation layers in this section dip southwestward from 10° to 30°. Southwestward along the strike in the valleys of East and South Branches of Codorus Creek, the dip of the foliation increases at a similar rate from south to north.

The foliation is cut by a transverse cleavage whose dip ranges from vertical to 80° NW. or SE. This cleavage is parallel to the axial planes of the minor folds and crinkles, is more prominent in the micaceous layers, and has smooth straight surfaces in contrast to the somewhat curved or irregular surfaces of the foliation layers.

In the area northwest of a line passing 1½ miles northwest of Brownton, 1 mile southeast of Graydon, and through Glen Rock and Sticks, no recumbent folds were observed. As far as the northwestern edge of the Martic overthrust block, the Wissahickon schist, the Marburg schist, and the associated quartzites show folded foliation layers with closely-spaced, steeply dipping, transverse cleavage.

The Paleozoic rocks of the adjacent Stoner thrust block are closely folded also. The folds and the transverse cleavage in them were formed during the later Mine Ridge folding, which affected the Martic thrust block as well; therefore, no divergence is apparent in the structure in the Paleozoic rocks and that in the Martic block at their contact.

The folds in the Tucquan anticline and on its flanks pitch in a southwesterly direction. The pitch averages 15° but in places the amount is as great as 30°. In a region with pitching folds the strikes curve. In this area no beds can be traced because the schist is made up of foliation layers that are not continuous for any distance; the lithology of the schists is similar throughout and for the most part outcrops are limited to stream valleys. The curving strike, however, is indicated by the variable direction of the strike of the lineation. This is well seen in the Tucquan anticline. At the Susquehanna River the axis of this anticline trends S. 70° W., whereas from High Rock southwestward it trends S. 40° W. The strike varies considerably also to the southeast. At Southside and southeast of that point for a distance of two miles, the strike is nearly north-south; and to the southeast, at Bryansville, it again trends S. 40° W.

GLEN ROCK ANTICLINE

In the Hanover York district the Tucquan anticline is recognized as an upfold because the foliation dips in opposite directions off the anticline. On the flanks of this anticline where foliation dips are overturned, major structures in the schists cannot be recognized with certainty. Elongate areas of metabasalt are infolded in the Wissahickon formation northwest of the Tucquan anticline and southeast of the Wentz syncline. The axial planes of the folds in these rocks dip northwest, and the amount of dip increases from 35° near Anstine to 70° at a point north of Glen Rock. These areas of metabasalt and associated Wakefield marble near the Maryland state line are regarded as anticlinal because in Maryland, where they are more widely exposed, they appear to lie in large part beneath the albite-chlorite schist facies of the Wissahickon formation.

YOE SYNCLINE

In the Yoe syncline (fig. 27) the black slate and quartzites folded into the Marburg schist are believed to be the youngest beds present. In the York quadrangle, the transverse cleavage dips about 80° NW. between the Tucquan anticline and the axis of the Yoe syncline, which passes through Craley. From this axis to the edge of the Martic thrust block and in the Paleozoic rocks to the northwest, the cleavage dips 80° SE. The exposures of the rocks in the Yoe syncline are very

[29] Gilluly, James, Mineral orientation in some rocks of the Shuswap Terrane: Am. Jour. Sci., 5th ser., vol. 27, pp. 184–185, 1934.

poor because they occupy an upland area. East of the York quadrangle the eastward extension of the syncline passes out of the Marburg schist north of Long Level; and, on the east side of Susquehanna River north of Creswell, the syncline is in the Conestoga limestone, which, at that point, lies north of the schists of the Martic block.

WENTZ SYNCLINE

The Wentz syncline occupies the southern part of the Hanover quadrangle. (See fig. 27.) Southwest of the highway (US 111) the quartzites associated with the Marburg schist are infolded in the syncline, and near the Maryland state line, where the syncline is deeper, the quartzites are more widespread. The syncline is named from the village of Wentz, in Maryland, 1½ miles south of West Manheim. North of the Maryland line the main part of the syncline passes through Beecher Hill, Brodbecks, and Huntrick Hill, and quartzite is infolded as far northwest as Zumbrum School. In that area the transverse cleavage dips southeastward. Northeast of the valley of Codorus Creek toward the northeast end of the syncline, the transverse cleavage dips northwestward; and this direction of dip persists northwestward across the strike to the edge of the Martic overthrust block. The southeastward-dipping cleavage probably reflects overturning of the folds to the northwest, and the northwestward-dipping cleavage reflects overturning to the southeast, although most of the exposures are not good enough to verify this suggestion.

In a valley near Marburg where the schist is well exposed, the dip of the cleavage ranges from 80° NW. to vertical. To the southwest in a parallel valley the cleavage dips southeastward, and this direction of dip persists northwestward for 5 miles in the northwest part of the Martic block. The small folds, wherever visible, pitch from 50°–60° NW. Because of the discontinuity of outcrops, the strong development of transverse cleavage, and the prevailingly uniform micaceous character of the Marburg schist, the strike cannot be traced directly; but the pitching folds, wherever observed, indicate that the strike curves. Curved strike has been found in the quartzites to the south where the outcrops are more continuous; and from Brodbecks southwestward into Maryland, wherever exposed, the folds have inclined fold axes.

LOGANVILLE ANTICLINE

Blue crystalline limestone in the Loganville anticline, which lies between the Yoe and Wentz synclines, is exposed in a narrow valley northeast of Loganville. (See fig. 27.) In the Marburg schist on the north side of the valley the fold axes are horizontal, and the axial planes are overturned to the southeast. Folds pitch 45° SW. in the schist that divides the western part of the limestone area and forms a hill south of an abandoned limonite pit. Twelve miles southwest of the Loganville area, southeast of Zumbrum School, there is another uplift of limestone on the same general strike as the Loganville anticline. The only outcrop observed in this area was in an abandoned quarry east of the road along Codorus Creek, where grayish-white marble was exposed.

RELATION OF FOLDS IN THE PALEOZOIC FORMATIONS TO THOSE IN THE GLENARM SERIES

On the north flank of the Mine Ridge anticline, the true thickness and order of the stratigraphic sequence of the Paleozoic rocks that overlie the pre-Cambrian core of the fold can be determined from their base upward in the direction of the pitch. The schists, which largely overlie the Conestoga limestones and which are folded into the Tucquan anticline, also pitch southwestward; but the sequence of the schists cannot be determined, because of isoclinal and recumbent folding and the shearing out of the folds, which has greatly modified the original order of the beds. In this anticline, the Glenarm series and the Paleozoic formations are evidently folded together. North of the main body of the Martic overthrust block and of the valley underlain by Paleozoic rocks, on the Susquehanna River south of Shenks Ferry Station, the schists of the Glenarm series again appear on the east side of the river and continue from Shenks Ferry Station seven miles northward to Creswell Station. These schists also are folded with the underlying Paleozoic rocks, and the fold axes in both series dip southwestward. Because of the southwesterly pitch of the folds, erosion has removed the schists half a mile east of the river and has exposed the Paleozoic rocks whose folds in the region north of Safe Harbor plunge southwestward under the schist. The axial planes of the folds in both series dip northwest and the closely folded and overturned anticlines and synclines in the Paleozoic rocks pass southwestward into the schists of the Glenarm series. The metabasalt brought to the surface apparently in anticlines near Glen Rock and north of Shrewsbury Station may lie along one of these anticlines which can be recognized in the Paleozoic rocks. Also the Strasburg syncline may pass southwestward through Star Rock and into a synclinal area near Glen Rock. Farther to the northwest the Yoe syncline in the Marburg schist appears to extend eastward into the limestone area, north and east of the schist near Creswell Station. There it is called the Millersville syncline. The Yoe-Millersville syncline is not overturned. The bedding and cleavage in the Conestoga limestone a mile north of Creswell Station dip southeastward into the syncline. The schists south of Creswell Station, on the south side of the syncline, are well exposed, and the axial planes of the minor folds and the cleavage dip northwest into the syncline.

On the north side of this syncline and northwestward to the Hellam Hills and Pigeon Hills anticlines in the Hanover-York district, the folds are symmetrical or overturned to the northwest. The Yoe-Millersville syncline appears to be a major structure comparable to the Mine Ridge-Tucquan anticline on the south and the Hellam Hills-Pigeon Hills anticline on the north.

EVIDENCE OF OVERTHRUSTING

If the two superposed sequences are folded together, it may be asked: What is the structural evidence for the overthrust relationship of the rocks of the Glenarm series? In the Tucquan anticline of the York area, as has been stated, the schists of the Wissahickon formations contain two schistose structures, an older horizontal foliation, and steeply-dipping transverse cleavage in later folds. In the discussion of the albite-chlorite schist facies of the Wissahickon formation, evidence was given to show that the foliation is a "transposition" cleavage produced by slipping in closely appressed recumbent folds so that they are more or less completely sheared out and destroyed. Both megascopic and microscopic recumbent folds in the Wissahickon schist are shown in plate 9. The foliation structure, in which recumbent folds have been partly or entirely destroyed so that the schist is made up of thinly laminated, alternating micaceous and quartzose layers, is shown in plates 10 to 12. The quartzose layers are in large part discontinuous and form lenticles completely surrounded by micaceous envelopes, and lie parallel to the foliation in the schistose layers. If the layers in the micaceous and quartzose rocks were originally bedding, the foliation produced by slipping in the closely appressed recumbent folds is also largely parallel to the bedding; but, because the original position of the layers is completely transposed, the foliation layers do not represent a stratigraphic succession. These foliation layers have been crumpled and folded into the Tucquan anticline and the minor folds on its flanks, coincident with the upfolding of Mine Ridge anticline.

North of the Martic overthrust from near Quarryville to Shenks Ferry and Safe Harbor, the sequence of Antietam quartzite, Vintage dolomite, and Conestoga limestone occurs in bands repeated several times, with trends parallel to the erosional border of the schist. (See fig. 27.) At the celebration in September 1939 of the Pennsylvania Geological Survey's Twentieth Anniversary under G. H. Ashley as State Geologist, a series of papers was read on the age and structure of the Glenarm series. In one of the papers, Ernst Cloos described briefly his conclusions on his structural study of the Mine Ridge area. He was not then convinced that the Glenarm series was thrust over the Paleozoic rocks of the area but suggested that the repetition of the Paleozoic sequence north and east of Shenks Ferry may represent a series of overthrust plates. The writer agrees with Cloos' suggested explanation for the repetition of the Paleozoic sequence. Furthermore, she suggests that it was the northward push of the Martic overthrust that produced the thrust plates in the overridden Paleozoic rocks, and, as folding continued during the rise of Mine Ridge anticline, the thrust plates were folded with the overlying schists. The trend lines in this part of the area shown on figure 27 therefore represent the trend of the folded edges of the overthrust plates in the Paleozoic rocks. The trends in these overthrust plates are parallel to those in the overriding schists and the trend lines in both sequences were formed in the latter part of the regional folding.

The writer concludes that the recumbent folding in rocks of the Glenarm series is a manifestation of the movement by which they were extensively displaced and brought to lie in structural discordance over the Paleozoic rocks, and that the structures now visible and common to the Paleozoic rocks and the adjoining schist of the Glenarm series were produced in both groups during the main upbowing of Mine Ridge.

Recumbent folds are found also in the rocks of the Glenarm series in Maryland.[30] There, this series comprises the Setters formation, the Cockeysville marble, and the oligoclase-mica schist and albite-chlorite schist facies of the Wissahickon formation. Recumbent folds occur also in the Baltimore gneiss, which, in Maryland, underlies these formations. Recumbent folding was suggested [31] also for the major structure of the Woodville anticline, Chester County, Pa.

The recumbent folds seen throughout the area are on a small scale, and the magnitude of the folding cannot be determined in the field owing to the insufficient vertical extent of the outcrops. The small scale recumbent folds may reflect a large-scale structure developed during the forward movement of the Glenarm series when it was pushed over rocks of known Paleozoic age; hence the displacement may have been effected by large-scale recumbent folding. Because the folds are sheared out, the forward movement is represented by the sum of these small movements. A similar type of folding has been described in the Taconic area [32] of New England.

Metamorphism seems to have taken place in the schists of the Glenarm series during overthrusting and to have continued in the schists and the Paleozoic rocks during the rise of Mine Ridge anticline and after deformation was completed.

In the Hanover-York district no exposures have been found of the contact of the Marburg schist and the

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[30] Jonas, A. L., Tectonic studies in the crystalline schists of southeastern Pennsylvania and Maryland, Am. Jour. Sci., 5th ser., vol. 34, pp. 367–368, 1937.

[31] Bailey, E. B., and Mackin, J. H., Recumbent folding in the Pennsylvanian Piedmont; preliminary statement: Am. Jour. Sci., 5th ser., vol. 33, pp. 186–190, 1937.

[32] Prindle, L. M., and Knopf, E. B., Geology of the Taconic quadrangle: Am. Jour. Sci., 5th ser., vol. 24, pp. 293–298, 1932.

overridden Paleozoic rocks. The northwestern part of the Martic overthrust block is covered by Triassic rocks from 7 miles southwest of the Hanover-York district to a point east of the northeast end of the Frederick Valley. From that point southward across Maryland, the Ijamsville phyllite [33] largely of tuffaceous origin, forms the western border of the Martic overthrust and is in contact with Lower Cambrian Antietam quartzite and Upper Cambrian Frederick limestone. On Monocacy River, 7 miles south of Frederick, a contact of Ijamsville phyllite and Frederick limestone is exposed on the south side of the River. This contact surface dips 55° SE. The fold axes in the Ijamsville phyllite also dip 55° SE. The folds are in large part sheared out by cleavage parallel to the axial planes, which dip 75° SE. Tension joints healed by quartz cut cross the fold axes. The dip of the cleavage in the Frederick limestone at the contact is 55° SE., and on the cleavage faces are linear streaks parallel to the lineation and fold axes of the phyllite. The fold axes of the limestone are horizontal and strike N. 35° E., parallel to the contact. The structural discordance of the phyllite and limestone at the contact is obvious. In the Ijamsville phyllite and associated flows and marble that form the western border of the Martic overthrust in Frederick County, Md., the folds have steep axes,[34] a type of structure that is confined to these rocks and does not occur in the limestones of Frederick Valley to the west. The folds are in part sheared out by transverse cleavage and are compressed at right angles to the border of the thrust.

Folds with steep axes are supposed to have developed in response to a check [35] of forward movement; but the compression and shearing out of the folds took place during a later stage of the orogeny when the linear streaking was imposed on the cleavage of the Frederick limestone. The dip of the contact 55° SE indicates a rather steeply-dipping thrust plane at this point and probably elsewhere on the fault, which extends along the entire eastern side of Frederick Valley.

AGE OF THE STRUCTURAL FEATURES

The rocks of the Martic overthrust block rest on Conestoga limestone of probable Ordovician age. The date of the overthrust, therefore, is post-Conestoga. The Conestoga limestone is correlated with limestones containing Beekmantown fossils in Chester Valley,[36] hence, the thrust fault is probably of post-Beekmantown age. Because the major anticlines and synclines in the Paleozoic rocks and in the Glenarm series of the Hanover-York district are parallel to the late Paleozoic folds of the Appalachian Valley to the northwest, the folding in both areas is probably of the same age. This folding was later than the recumbent folding and formation of foliation layers that were developed during or before the forward movement of the Martic overthrust block. No evidence has been found to show whether the overthrusting of the Martic block and the latter folding took place during two stages of late Paleozoic orogeny, or whether the Martic overthrusting and recumbent folding took place in an earlier orogeny.

TRIASSIC STRUCTURE

STRUCTURAL FEATURES OF THE TRIASSIC ROCKS

The Triassic rocks that cover the northwest third of the Hanover quadrangle are not folded, as are the older rocks to the southeast; but they are gently tilted northwestward at an average angle of 30°, and in places are displaced by normal dip faults. In the adjacent region, normal strike faults occur within these red beds, but no strike faults have been observed in the Triassic rocks of the Hanover quadrangle. The Triassic rocks are part of a great block that has been faulted down at its northwestern margin, 10 miles northwest of the Hanover quadrangle. During the faulting all the Triassic rocks in the block were tilted northwestward. The major part of this faulting and tilting, therefore, probably occurred at or near the close of the Triassic period, when conditions were favorable for the formation of normal faults, the sinking and tilting of blocks, and the intrusion of diabase into the sedimentary rocks through the openings made by faulting in the floor of the basin.

South of Abbottstown two converging dip faults unite, and the base of the northwestward-dipping Triassic rocks is offset more than half a mile. The basal conglomerate east of Beaver Creek School is offset northward to the road east of Walnut Grove School. Outcrops of slickensided and crushed conglomerate along this fault can be seen on the highway (State 190). Two other dip faults offset the base of the Triassic series just west of La Bott. The combined horizontal displacement here is also about one-half mile. Just east of Paradise Creek, the conglomerate bed, slickensided by the fault movement, is exposed along the road extending northeastward from Farmers. A pebble of milky white quartz, cut in two and polished by the fault movement, is shown in plate 15, *C*.

TRANSVERSE FAULTS IN THE PALEOZOIC ROCKS

Several transverse faults that cut the Paleozoic rocks trend, in general, N. 30° W. They terminate in normal strike faults that trend N. 50° to 60° E. Intersection of the two sets of faults tends to produce a rhombic fault pattern. (See fig. 28.)

[33] Jonas, A. I., and Stose, G. W., New formation names used on the geologic map of Frederick County, Maryland: Washington Acad. Sci. Proc., vol. 28, p. 346–347, 1938; Geologic map of Frederick County, Maryland, Maryland Geol. Surv., 1938.

[34] Jonas, A. I., op. cit. (Am. Jour. Sci., 5th ser., vol. 34), pp. 376–385, 1937.

[35] Idem., p. 385.

[36] Stose, G. W., and Jonas, A. I., Age reclassification of the Frederick Valley (Maryland) limestone: Geol. Soc. Amer. Bull., vol. 47, pp. 1671–1673, 1936.

A cross fault that strikes about N. 30° W. cuts the end of the Mount Zion anticline, crosses the limestone lowland east of York, and follows Mill Creek to Plank Road, and hence is called the Plank Road fault. It offsets the Stoner overthrust a quarter of a mile, the west side having moved relatively northward. The Antietam quartzite and higher formations on the south limb of the Wrightsville syncline, just north of the Stoner overthrust, are similarly offset. To the south in the gorge of Mill Creek, the quartzite beds in the Chickies slate and the infolded Harpers phyllite are broken and offset in the same direction. The relative horizontal movement on this part of the fault is therefore the west side moved northward. On the north limb of the Wrightsville syncline, the Kinzers formation and Vintage dolomite east of the cross fault are terminated abruptly by the fault, but the absence of exposures in the Mill Creek lowland west of the fault and the complication due to the presence of a strike fault, obscure the direction of movement on the fault. Farther north the Highmount overthrust is offset northward on the west side of the cross fault, similar to the offset of the Stoner overthrust. The cross fault terminates at the Glades overthrust.

A nearly parallel cross fault follows the local course of East Branch of Codorus Creek southeast of West York, and passes near the York Country Club, and is, therefore, called the Country Club fault. It offsets the Stoner overthrust northward on the east side. South of this overthrust, Harpers phyllite west of the cross fault is in contact with Chickies slate to the east. In the limestone of the valley north of the Stoner overthrust, an anticline that brings up Kinzers formation and Vintage dolomite is cut in two; but the parts of the fold do not match. Evidence of the direction of movement on this fault, therefore, is conflicting. The Country Club fault

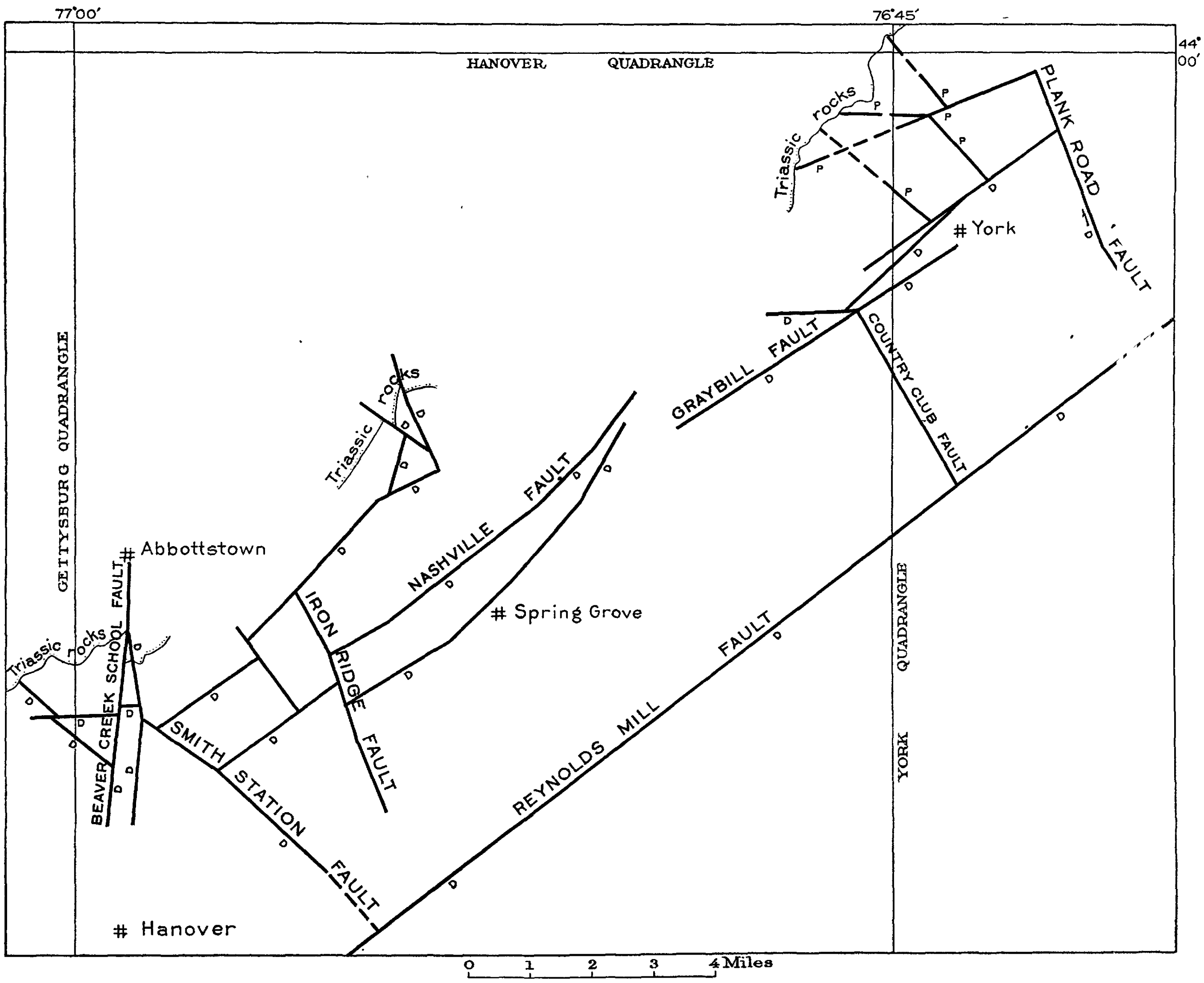

FIGURE 28.—Map of normal tension faults in the Hanover quadrangle and adjacent part of the York quadrangle. D, downthrown side. Arrow shows direction of relative horizontal movement. Observed relation of faults to Triassic rocks shown. Faults marked *P* apparently affect only the Highmount thrust block and are believed to be of late Paleozoic age.

terminates at the north in the Graybill fault, which is apparently a normal strike fault downthrown to the south. The Country Club and the Plank Road cross faults appear to end at the south in another strike fault, the Reynolds Mill fault, which also is downthrown to the south.

Several nearly parallel cross faults, marked P in figure 28, break up the rocks in the Highmount overthrust northwest of York but do not pass into the overridden limestone. These faults apparently represent part of the fragmentation of this thin plate during overthrusting, as described under Mount Zion anticline, and, therefore, are believed to be of Paleozoic age.

The Pigeon Hills anticlinorium is cut almost at right angles by several transverse faults. Near the west end of the anticlinorium two nearly parallel faults, the Beaver Creek School faults, converge and join to the northward. These faults not only offset the structures in the older rocks but extend into and offset the Triassic rocks to the north and, therefore, in part at least, are of Triassic age. Two other cross faults, which terminate the north arm of the High Rock anticline, also cut and offset the Triassic rocks between Farmers and La Bott and, therefore, at least in part, are also of Triassic age.

The Iron Ridge cross fault, which trends about N. 30° W., breaks across and offsets the folds of the Pigeon Hills anticlinorium near Gnatstown. (See pl. 17 and fig. 28.) At Iron Ridge it offsets the Stoner overthrust northward on the west side. This fault terminates at the north in a northeastward-trending normal fault within the High Rock anticline. A shorter parallel cross fault, one mile to the west, also cuts the Pigeon Hills anticlinorium, apparently breaks the northeastward-trending normal fault referred to previously, and at the south terminates in another northeastward-trending normal fault. A cross fault that trends more to the northwest cuts off the southwest end of the Gnatstown anticline and terminates at the north in the east branch of the Beaver Creek School fault. Southeastward this fault crosses the limestone lowland, and offsets the Stoner overthrust at Smiths Station. It is therefore called the Smiths Station fault. The thin remnant of the Stoner overthrust block is considerably dissected east of this fault, and in the vicinity of Smiths Station the east side seems to be relatively uplifted to such an extent that erosion has removed the rocks above the overthrust and produced the large embayment at Penn Grove.

AGE OF THE TRANSVERSE FAULTS

The Country Club and Plank road cross faults cut and offset the Stoner and Highmount overthrusts and other structural features of the area. They and the associated normal strike faults, therefore, are younger than these structural features, and may be partly, or wholly of Triassic age. The Iron Ridge, Smiths Station, Beaver Creek School, and other cross faults similarly cut across the structural features of the Pigeon Hills and offset the Stoner and Gnatstown overthrusts. Some of them also cut and offset the Triassic beds and, therefore, in part at least, are of Triassic age. It is probable that the faulting and adjusting of blocks took place under conditions of tension at the beginning of the Triassic period, during the formation of the basin in which the Triassic sediments were later deposited. Many places along the northwest border of the Triassic rocks show evidence of such early Triassic faulting during the formation of this basin and its progressive sinking.

GEOLOGIC HISTORY

The geologic record is plainer in the northern and central parts than in the southern part of the Hanover-York district; and for this reason the two parts are described separately.

In later pre-Cambrian time the northern part of the district was receiving outpourings of both basaltic and rhyolitic lavas. The exposures of these lava flows in this area are small, but observations farther to the southwest indicate that contemporaneous volcanic flows, mixed with ash, breccias, and clastic debris, were widespread. The volcanic rocks were spread over an older pre-Cambrian crystalline injection complex, which is now hidden in this area but is exposed northeast of the Susquehanna River. There, volcanic rocks either were never present or were removed by erosion before the basal sediments of Lower Cambrian age were deposited on the earlier injection complex. The pre-Cambrian injection complex in adjoining areas was composed originally of sandstone, shale, and limestone that were later intruded by gabbro, folded, permeated with material from granitic magma, and metamorphosed into schists and gneisses during the intrusion of large masses of igneous rock. Residual liquids of the intruding magmas formed pegmatite veins, which cut the layered gneisses formed earlier. The resultant injection complex covered a wide area in the Appalachian region in pre-Cambrian time, and was intensely folded and eroded before the later volcanic flows were poured out. The only clue to the age of the intrusive igneous rocks that form such a large part of the old complex comes from the pegmatites in Pennsylvania and Virginia. Analyses of radioactive minerals indicate that the pegmatites were formed over 800 million years ago. The volcanic rocks are much younger and probably represent the last stage of pre-Cambrian history.

Following the extrusion of the lavas, the land was elevated and eroded before the region was submerged in Lower Cambrian time. Clastic debris was then washed into the sea by streams from an old land area to the southeast. The first sediments were largely unsorted quartz sand, feldspar grains, clay, and coarser round pebbles of milky and glassy quartz. These deposits are now represented by the Hellam conglomerate member of the Chickies quartzite. The coarse cobbles found in the Hellam conglomerate in the vicinity of the Hellam Hills may indicate a local shoaling of the sea at this point while off-shore material was being contributed elsewhere. Following these early sediments, purer, well-sorted quartzose sands of the Chickies quartzite were deposited. Some distance southeast of the Hellam Hills area, clayey mud and some quartz sand of the Chickies slate was being deposited at this time. Fine clay and silt, now represented by the Harpers phyllite, collected in the sea before a closing stage of the terriginous deposition, furnished the quartz sand of the Antietam quartzite. The presence of life is not recorded in the lower beds of the Cambrian system; but the borings of sea worms, *Scolithus linearis*, are numerous in the massive beds of the Chickies and Antietam quartzites, and trilobites and brachiopods, which lived along the shore of this sea, are preserved in the upper layers of the Antietam quartzite. About 2,500 feet of quartzose and clayey material was deposited in the Lower Cambrian sea before the waters cleared and carbonate sediments, derived from the sea water by precipitation aided by organic life, together with small amounts of clastic material, were deposited. These sediments formed the Vintage dolomite, followed in this area by a series of impure carbonate, clayey, and sandy beds of the Kinzers formation. Trilobites and brachiopods were abundant in the sea at this time and are more numerous and better preserved in the rocks of the Kinzers formation than in the earlier carbonate rocks. The purer limestone beds of the Kinzers contain reefs of archaeocyathids which are probably fossil sponges. While the clayey and limy silts of the Kinzers formation were being deposited in this part of the sea, purer carbonate sediments accumulated continuously in the Lower Cambrian farther to the northwest. Pure lime silt, which followed the impure beds, eventually became the Ledger dolomite. The Lower Cambrian carbonate rocks may have been deposited as calcium carbonate, and their partial or complete change to dolomite may have occurred at a somewhat later time.

Carbonate sediments were deposited during the rest of Cambrian time in adjacent regions, but no traces of these rocks are known to be preserved in the Hanover-York district unless the Conestoga limestone is in part of Upper Cambrian age. The region was uplifted and stood above sea level in late Cambrian or early Ordovician time, and some of the recently deposited sediments were eroded from the land before it was resubmerged and the Conestoga limestone was deposited. In the Hanover-York Valley, the Conestoga limestone lies on Ledger dolomite and Kinzers formation; but south of the Stoner overthrust, it overlaps on the Antietam quartzite, with the Vintage dolomite and Kinzers formation exposed in a few places. At the beginning of Conestoga time the sea invaded an irregular land surface on which there were large and small blocks of white marble residual from the older formations These fragments were transported only a short distance from their source and were engulfed in the calcareous silt of the Conestoga. The white marble blocks contain no fossils but resemble beds of the Kinzers formation. The old land surface furnished white quartz sand, which was carried by streams, or blown by the wind, into the sea and incorporated in the early calcareous mud deposits. Consequently, limestone containing abundant rounded quartz grains is a characteristic part of the lower beds of the Conestoga. The sea was of variable depth; and in places, wave action broke the recently formed layers into tabular blocks, which came to rest at varying angles in the calcareous ooze and were consolidated into the edgewise and intraformational conglomerates that are interbedded with the argillaceous and siliceous limestones of the Conestoga. Intraformational and edgewise conglomerates are most plentiful in the lower part of the formation. The alternate accumulation of fine calcareous silt and argillaceous silt, containing a variable quantity of carbonaceous material, continued after the basal conglomerate was formed, and the larger part of the formation is composed of these impure limestones.

There is no record that Paleozoic sediments were deposited in this district after Conestoga time. Farther northwest, sediments were deposited during the remainder of Paleozoic time, and they aggregate many thousand feet in thickness. The formations in the Valley and Ridge province represent these later rocks.

Before discussing the period of folding and mountain building that affected the entire Appalachian region at the close of Paleozoic time, the geologic history of the southern part of the district will be described. The Glenarm series was deposited in a basin that lay some distance to the southeast of the present position of these rocks. The floor of the depositional basin is not seen in this district; but farther to the southeast near the southeastern border of the Piedmont Plateau, the floor is exposed in several upfolds. This basement is formed by pre-Cambrian Baltimore gneiss and Hartley augen gneiss. These gneisses resemble those of the floor on which the later pre-Cambrian lava flows of the Hellam Hills and Pigeon Hills are believed to have been extruded. The source of the sediments of the Glenarm series was a land area still farther to the southeast in the region now covered by the sediments of the Coastal Plain.

The earliest sediments deposited in this southern sea were arkoses, finer arkosic and quartz sands, and argillaceous muds. After the accumulation of the feldspathic sand and silt, rather pure calcareous material was deposited and was followed in the southeastern part of the sea by a thick series of arenaceous and argillaceous sediments. This phase of the Glenarm series, which has been metamorphosed into the Setters formation, the Cockeysville marble, and oligoclase-mica schist facies of the Wissahickon formation, together with the underlying Baltimore gneiss, is now exposed to the southeast of the Hanover-York district. In the northwestern part of this southern basin, volcanic activity began during the formation of the calcareous sediments. The volcanic deposits were in part submarine because the rhyolite and basalt flows were mixed with volcanic ash and quartzose terriginous sediments. Volcanic materials, mostly pyroclastic, continued to be deposited and are interbedded with the later accumulation of coarse and fine clastic siliceous material. These sediments are now represented by the Wakefield marble, which may be contemporaneous with the Cockeysville marble; metabasalt flows; rhyolite flows, and tuffs, including the Urbana and Ijamsville phyllites most widely distributed in Maryland; the albite-chlorite schist facies of the Wissahickon formation; and the Marburg schist and associated quartzites. In the southeastern part of the area, southeast of the York-Hanover district, the Glenarm series was later intruded by igneous rocks which range in composition from granite, through granodiorite, diorite, and gabbro to serpentine and pyroxenite.

The deposition of the Glenarm series and the igneous activity that followed were completed before Cincinnatian time. The rocks of the Glenarm series were later greatly metamorphosed and closely folded. The present position of the rocks of the Glenarm series upon the Paleozoic rocks to the northwest is the result of overthrusting, which occurred after the deposition of the Conestoga limestone in Ordovicion (?) time. The small scale recumbent folds seen in the rocks of the Glenarm series suggest large scale recumbent folding during the northwestward movement of these rocks along the Martic overthrust. Although the rocks of the Glenarm series cannot be definitely dated, their deposition and accompanying volcanic activity probably occurred late in pre-Cambrian time.

The main overthrusting probably began early in the period of compression and mountain making that took place at the close of the Paleozoic era, when the rocks of the Hanover-York district and the entire Appalachian region were closely folded and raised above sea level.

Metamorphism, which began in the rocks of the Martic overthrust block during recumbent folding and thrusting, continued in both the overthrust rocks and the overridden Paleozoic rocks during the late Paleozoic deformation that compressed both series into folds with northeastward trends parallel to the trends in the main Appalachian region to the northwest. Many of these folds are overturned toward the northwest and are broken by thrust faults along which the rocks moved northwestward. This folding and overthrusting moved the rocks of the Stoner block and of the Hellam Hills and Pigeon Hills anticlines farther northwestward. In places the folded and overthrust rocks are broken by normal faults, some of which represent the last stages of this deformation.

After the Appalachian orogeny, the elevated region was eroded until the Triassic period, when an elongated basin was formed in the upland surface by downwarping and by normal faulting chiefly at the west edge of the area. The trend of the basin in part parallels the older structures and in part cuts across them in a more northerly direction. The red sands and clays of the Newark group, which was deposited in this basin, were derived from higher land to the southeast. The crystalline rocks on this upland were deeply weathered and disintegrated, and furnished the quartz and the feldspathic sand, the clay, the flakes of mica, and the red iron oxide, which accumulated in the basin to a great thickness Downfaulting and progressive sinking at the northwest edge of the basin caused the ovelapping of beds toward the western part of the area and tilted the beds rather uniformly northwestward. Toward the close of Triassic deposition, the great fault break in the floor near the west edge of the basin offered a means of escape for basaltic magma. The lava welled up also along vertical joints in the Triassic rocks, and hardened into diabase dikes. The larger part of the magma was injected between layers of the sedimentary rocks and hardened as great sills of diabase, such as the one in the northwest corner of the Hanover quadrangle. Heat and hot water from the intruded diabase baked the adjoining Triassic sedimentary layers and changed their color from red to dark gray or bluish black. Some of the smaller dikes that came up through the Paleozoic and pre-Cambrian rocks beneath or south of the Triassic sediments extend entirely across the district to the Maryland State line.

At the close of Triassic time, further movement on the faults at the west edge of the Triassic basin tilted the Triassic rocks still more so that now they all dip toward the northwest edge of the basin where they terminate against a marginal chain of normal faults. The Triassic rocks in this area were also broken by vertical dip faults, which in places offset the beds and their basal boundary about half a mile.

Since Triassic time the district has been continuously above the sea. Except alluvium along the larger streams, no sediments have been deposited but on the contrary, the land has been extensively eroded. At the beginning of Cretaceous time, all the rocks, including the hardest and most resistant, were worn down to a nearly level, gently rolling surface near sea level, forming the Schooley peneplain. During Tertiary time this surface was raised and again was subjected to erosion. Remnants of the Schooley peneplain are preserved in the Pigeon Hills at an altitude of 1,140 feet and, in the southern part of the district, at about 1,000 feet. The rolling upland in the southern part of the York quadrangle attains a rather uniform level, mostly ranging from about 900 to 1,020 feet in altitude with a few points 20 to 40 feet higher. This flat upland surface is best shown at Shrewsbury, Mt Airy School, Mt. Olivet Church, and the hilltop southeast of Winterstown. The flat top of this hill is 1,020 feet in altitude and covers nearly half a square mile. The flat hilltop in the vicinity of Mt. Olivet Church is from 1,000 to 1,020 feet in altitude and extends in a northerly direction almost continuously for more than two miles. Smaller flat uplands are at the same general level on Rocky Ridge, Dug Hill and its extension southwest of Sticks, and the hills in the northern part of the Wentz syncline southwest of Beecher Hill. These flat surfaces at approximately 1,000 feet altitude probably represent the Schooley peneplain, and the writers believe that these levels have been little reduced by erosion since they were formed. Flat hilltops that stand about 900 feet above sea level, however, may have been reduced 100 feet or more by erosion. Ashley[37] believes that these mature elevated surfaces have been greatly reduced since their formation by erosion and weathering, possibly at the rate of 1 foot in 10,000 years, but that the remnants still preserve their level character. The writers do not agree with this view.[38]

The Pigeon Hills, 10 miles north of the hills of the Wentz syncline, rise to altitudes of 1,000 to 1,240 feet. The Schooley peneplain is probably here represented by a rather flat bench at 1,140 feet, which is 120 feet higher than the Schooley level 10 miles to the southeast in the southern part of the district. Two rocky peaks that rise above this bench are probably monadnocks on the Schooley peneplain. In this district the Schooley surface, therefore, slopes about 120 feet in 10 miles, or 12 feet to the mile. Flat tops of ridges in South Mountain, Adams County, 20 to 25 miles northwest of the Pigeon Hills, rise to an altitude of about 1,600 feet but are less extensive than the broad flat top of South Mountain, called Big Flat, whose altitude is 2,050 feet. This flat surface is regarded by the writers as a remnant of the Schooley peneplain. The marked discrepancy of this level with that of the Schooley peneplain on the Pigeon Hills and in the area to the southeast, has been explained by Stose[39] as due to post-Cretaceous faulting.

By the close of Tertiary time, the softer rocks at the surface were again reduced by erosion to a gently sloping, nearly level plain, and remnants of this surface, called the Harrisburg peneplain, are preserved at altitudes ranging from 620 to 520 feet. The flat-topped hills of Triassic sandstone and shale in the northwestern part of the Hanover quadrangle, range in altitude from 520 to 560 feet and probably represent the Harrisburg peneplain. The limestone in the flat lowland around Hanover is deeply weathered and has almost no outcrops, indicating long exposure to the agents of weathering and little reduction of level by erosion. This lowland, which is from 600 to 620 feet in altitude and forms the divide between streams that flow eastward into the Codorus and westward into the South Branch of the Conewago, probably also represents the Harrisburg peneplain.

The present mountains, valleys, and lowland have been sculptured out of the rocks in these uplifted surfaces.

MINERAL RESOURCES

The chief mineral resource of the Hanover-York district is limestone, which is extensively quarried for lime burning, cement manufacture, and crushed stone. Iron ore was mined formerly to a considerable extent, but none of the mines are being worked at present. Sand and clay are dug locally for building purposes and for brick manufacture. Slate has been prospected at several places, but none has proved of suitable quality for roofing purposes. Red Triassic sandstone, Lower Cambrian quartzite, and in the southeastern part of the area quartzite, metabasalt, and mica schist are used locally in building dams, bridge piers, walls, and stone fences. The descriptions of quarries that follow present the conditions that existed in 1937 or earlier.

HIGH-CALCIUM LIMESTONE

Limestone of unusual purity occurs in the middle member of the Kinzers formation. In most places this pure, high-calcium rock is too thin to be quarried on a large scale; but in the York Valley, from York to Thomasville, it attains a thickness of 100 feet or more and has been extensively quarried. Many old quarries were located in and around the city of York, but most of them have ceased operation. This pure limestone is now actively quarried in the Hanover-York district by 4 companies; and similar high-grade rock probably underlies much of the area mapped as the middle member of the Kinzers formation northwest and west of York and in the vicinity of Thomasville. For a detailed description of the limestone quarries in the area, as well as the technology of the industry, the reader is referred to Miller's comprehensive report[40] on the limestones of the State. The product is used for whiting, portland cement, flux in the steel and glass industries, and, either raw or burned, for agricultural lime.

The Palmer Lime and Cement Co. plant, now operated by the Universal Gypsum & Lime Co., is in the southern part of West York, on a branch line of the

[37] Ashley, Geo. H., Weathering and erosion as time markers (abstract): Geological Soc. America Proc. for 1937, p. 70, 1938.

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

[39] Stose, G. W., Possible post-Cretaceous faulting in the Appalachians: Geological Soc. America Bull., vol. 38, pp. 493–504, 1927.

[40] Miller, B. L., Limestones of Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. M 20, pp. 9–112, 702–712, 1934.

Pennsylvania Railroad. Sketches of the active quarries of the company, as well as several abandoned pits, and details of structures exposed in the quarries are given in figures 11 to 13. The rock in the large quarry ranges from a compact dark impure limestone mottled with dolomite at the base, said to contain 28 percent $MgCO_3$, through a purer white marble mottled with gray, said to contain 18 percent $MgCO_3$, to a still purer compact white marble, which grades upward into gray mottled or spotted "calico rock," of higher magnesium content at the top. The high-grade rock is reported to contain from 98 to 99 percent $CaCO_3$. The large quarry south of the plant is about 1,000 feet long by 600 feet across and has a 50-foot face. Radiating tracks converge to the inclined tram that leads to the crushing plant north of the quarry where 2 crushing and pulverizing mills and 10 vertical steel kilns are located. The new quarry to the northeast is connected with the old quarry by tunnels under the roadway, and tunnels also follow the high-grade rock beneath the plant. The high-grade rock is carefully hand picked, and some is burned for lime and some is crushed and pulverized raw for shipment.

The Thomasville Stone & Lime Co. has a large quarry and plant half a mile south of Thomasville, on the Western Maryland Railroad. The quarry is about 1,000 feet long and its semicircular face is about 50 feet high. The limestone beds are nearly horizontal and have been tested by drill to a depth of 200 feet. The rock in the quarry is a high-calcium limestone, and rock of the same quality is reported to extend to a depth of 100 to 150 feet below the floor. A shipment of 40 carloads of crushed rock was reported to average over 98 percent $CaCO_3$, and 10 carloads shipped to the Midvale Iron & Steel Co. were reported to have averaged 99.69 percent $CaCO_3$. Some of the rock is burned for lime and some is granulated and pulverized raw for steel and glass plants. The less pure rock is crushed for road material. The equipment consists of 2 well-drilling rigs, 1 stripping shovel, 3 loading shovels, 14 vertical steel kilns, and crushing and pulverizing plants. Radial tracks converge toward the inclined tram running to the crushing plant.

The J. E. Baker Co. has a large quarry and plant just south of Thomasville. An inclined tram runs to the crushing plant. The company has another quarry north of the Lincoln Highway at Thomasville, but it was closed at the time of visit. This second quarry is also equipped with inclined tram to the crushing plant. High-grade rock is burned for lime in eight steel kilns, and some is pulverized raw. Less pure rock is crushed for road material. This company has a quarry also in similar high-grade rock 1½ miles west of West York south of the Sandusky Cement Co. quarry.

The Sandusky Cement Co., formerly the Medusa Portland Cement Co., has a large quarry and plant 1½ miles west of West York and is reached by a spur from the Western Maryland Railroad. The rock is a high-calcium gray to white marble of the Kinzers formation. The quarry is about 300 feet in diameter and has a 40-foot face. A concrete tower and storage bins and the crushing plant are reached by an inclined tram. The crushed rock is conveyed to the cement mill at West York, where Medusa white and gray portland cements are produced in a long rotary kiln. The product is stored at the mill in two large vertical concrete bins.

IMPURE LIMESTONE

Limestone and dolomite are burned for lime or ground and pulverized raw for agricultural use. Impure limestone and dolomite are crushed for road material and concrete. Small abandoned quarries, from which limestone was obtained formerly and burned for local use, occur throughout the area where limestone is exposed; and similar rock is available for these purposes in areas mapped as limestone. Only the larger active quarries will be described.

The York Valley Lime and Stone Co. quarry, now inactive, is adjacent to the Lincoln Highway north of Campbell. (See fig. 14.) A narrow gage track extends south from the quarry to the Pennsylvania Railroad. The rock is largely limestone conglomerate and impure slaty limestone of the middle part of the Kinzers formation and was used chiefly for crushed stone for highway construction. An inclined steel-car cable-tram leads from the radial tracks in the quarry to a crushing plant with elevated concrete bins above the tracks. A steam shovel was used for stripping. Steam drills were used in the quarry, and the company had two well-drilling rigs. The product was shipped by rail and motortruck. Formerly, the purer rock was burned for lime in 12 kilns located south of the highway, but these have not been in use for several years. The quarry was operated for a time by the U. S. Gypsum Co. but was idle in 1937.

The Eli Zinn Co. operates two quarries in the area for crushed stone. Their largest quarry is in the impure dark-blue slaty limestone of the upper part of the Kinzers formation on the south side of Highland Park Hill at Codorus Creek, south of York. (See fig. 16.). The quarry is about 200 feet long and has a face about 100 feet high. The other quarry is in the purer limestone and marble of the middle part of the Kinzers formation on the northeast slope of Greenmount Cemetery Hill. Both quarries are equipped with a crushing plant, screens, and storage bins; and the product is hauled by motortruck.

The York Stone & Supply Company has two quarries on the east face of Greenmount Cemetery Hill (fig. 10). The blue and white limestone of the Kinzers formation is crushed for road material. Sandy beds at the top of the old, deeper quarry are fossiliferous.

The Cunningham Crushed Stone Co. has a large quarry in massive Ledger dolomite northeast of York, near Mill Creek, but it was idle in 1937 and is probably abandoned. Sketches of a fault exposed in this quarry are given in figure 29. Across the road from this quarry the Standard Concrete Products Co. operates a quarry in banded limestone and dolomite of the Vintage formation. The rock is crushed and ground, and is used in the manufacture of concrete building blocks.

The A. M. Hake Co. formerly quarried stone in the northeast part of York; but the extension of the city has encroached on the quarry and it was abandoned. (See fig. 15.) The deep hole of the old quarry, is now filled with water and used as a dump for rubbish.

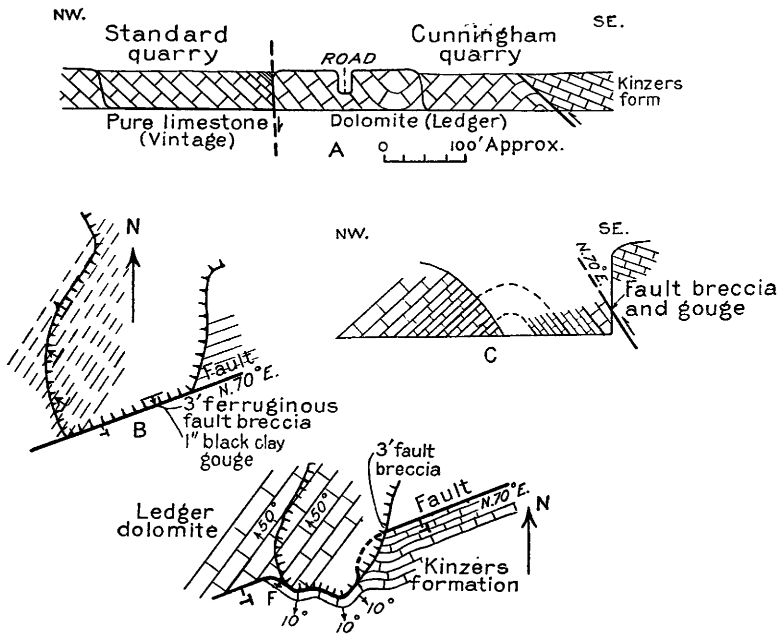

FIGURE 29.—Sketches of faults in quarries northeast of York: A, Generalized cross section through quarries of Standard Concrete Products Co. and Cunningham Crushed Stone Co.; B and C, Sketch of plan and cross section of Cunningham quarry in 1921, showing detail of structure near the fault contact and accompanying breccia and gouge; D, Sketch of plan of present Cunningham quarry, showing detail of structure at fault. Trilobites were collected at point marked F.

The Roy Bittinger Co. has a quarry for crushed stone in the southwest part of Spring Grove adjacent to Codorus Creek. The rock is the thin-bedded crystalline blue limestone with argillaceous banding and the massive impure limestone of the Kinzers formation. Sketches of faults and other structures exposed in this quarry are given in figure 18. Trilobites were obtained from the thin-bedded crystalline limestone in this quarry.

BRICK CLAY

In the Hanover-York district, bricks are made from the residual clay from impure limestone and from ground shale and slate. The impure Conestoga limestone yields the thickest deposit of clay and has furnished the material used in the plants around York. Similar clay occurs in much of the area mapped as Conestoga limestone in the York-Wrightsville Valley.

Several brick plants are located in the outskirts of York. Two plants within the built-up part of the city, are now abandoned. The Wm. H. Grothe Brick Co.'s plant is southeast of the city, south of the East Prospect road. Here a large area has been stripped, exposing closely folded hard impure crystalline Conestoga limestone. (See pl. 7, *B* and *C* and fig. 19.) Some layers of very impure schistose limestone are 20 feet thick and are deeply weathered to a sericitic clay which is the chief source of the clay used. The plant consists of a long drying shed and three Dutch kilns.

The Spring Garden Brick Plant, east of York on the Maryland and Pennsylvania Railroad, also is in disintegrated argillaceous Conestoga limestone. The plant is equipped with six beehive kilns and a long drying shed. The chief product is a high-grade building brick of pleasing color, called colonial brick.

Brick made from ground slate was formerly produced 1 mile southeast of Spring Plains. The quarry was in Chickies slate in the hills south of the plant, and was reached by a tram road which connected with the Pennsylvania Railroad east of Spring Plains. The deep quarry is now filled with water, and the plant and railroad track are dismantled. South of Hanover, brick was made from the residual soil of shale of the Kinzers formation. The pit was 400 feet long and 15 feet deep. This plant is dismantled and the pit abandoned.

The Peerless Brick Co. has a plant on Codorus Creek north of York, just below the Elmer King sand quarry. The white sand from the quarry is mixed with clay from other sources, and a smooth white compressed brick is made. A lime-sand brick is also produced. The plant was not in operation at time of visit in 1936.

BUILDING SAND

Sand is obtained in the Hanover-York district chiefly from disintegrated quartzite and from the crushing of harder quartzite. The Chickies quartzite in Mount Zion Hill and in the Pigeon Hills is the chief potential source of this sand. Some residual material is also obtained from disintegrated sandy limestone. Such beds occur locally in the Conestoga limestone in the vicinity of Hanover.

The only active sand operations in the area are at the quarries of Elmer B. King and Bro. and the Neuman Sand and Supply Co. in the gorge of Codorus Creek, 2 miles north of York. Two quarries are opened in the Chickies quartzite above the Pennsylvania Railroad, and the product is brought by gravity to the crushing plants at the railroad. The lower quarry is about 20 feet wide and has a 30-foot face. The upper, larger quarry has a length of about 300 feet into the hill and a 40-foot face. The rock is crumbly thin-bedded gray to purplish rusty-weathering quartzite, which contains some harder vitreous beds. The rock is crushed, ground, and screened, and delivered to storage bins above the loading platform. The product is loaded into cars and trucks by gravity

Sand from disintegrated white arkosic quartzite of the Hellam member of the Chickies was obtained on Mount Zion Hill southeast of Pleasureville. The pit was operated by W. J. Herman, and considerable sand was taken from a pit 12 feet deep. Disintegrated quartzite beds in the Chickies slate south of the York valley were quarried on the Dallastown Pike 2½ miles southeast of York. Clay also was obtained at this quarry. Another old sand pit in this quartzite is on the top of Violet Hill 1 mile south of the reservoir south of York. This pit exposes much crushed and brecciated schistose quartzite, deeply stained with iron and injected with quartz veins, which mark a fault zone. Sand was dug from disintegrated quartzite at the top of the Marburg schist 1½ miles east of Red Lion. Disintegrated Triassic diabase is a local source of sand on State Highway 190 in the northwest corner of the Hanover quadrangle.

The Hershey Sand Co. has a pit in disintegrated sandy limestone in the northeastern part of Hanover, where highly sandy limestone beds in the Conestoga limestone have disintegrated into a rough ferruginous sand, which is dug and screened and used for building purposes. (See pl. 8, *A* and *B*.) The quarry was inactive in 1936, except for desultory hand screening of loose material. This pit is in the same beds as those more extensively exploited in the Conestoga limestone near McSherrystown in the adjacent Gettysburg quadrangle.[41]

SLATE

Slate has been prospected at several places in the area, but none of roofing quality has been found. One mile southwest of Kinney School in the Hanover quadrangle, a quarry 20 feet deep exposes black to gray smooth-splitting slate at the top of the Marburg schist, and some large thin slabs were quarried for flagstones. Half a mile east of Zumbrum School, similar slate at the top of the Marburg schist was prospected for roofing material. Black slate was quarried from the Chickies just south of Plank Road, but the slate is too fissile for roofing purposes. Two slate quarries were opened by L. P. Litsinger of York on Kreutz Creek southwest of Yorkana. In both quarries thin quartz layers are interbedded in the black slate.

STONE

Quartzite is quarried for building purposes in many places in the area. The thinner-bedded rocks are split into slabs of suitable size for foundations, bridge piers, and walls. The Chickies quartzite is the chief source of such stone, and the geologic map shows the areas of outcrop.

Stone has been obtained at several quarries in the Chickies quartzite, on the south slope of the Pigeon Hills north of Hanover. The two largest stone quarries in the area are 2 miles west of Spring Grove. Similar stone has been quarried in the Hellam member of the Chickies quartzite on the south slope of Mount Zion Hill, northeast of York.

Stone is also obtained from quartzites in the Chickies slate at two quarries near the York and Windsor Electric Railroad, 1 mile southeast of Violet Hill, and on Mill Creek near Benroy. Blocks are quarried for foundations, and some rock is crushed for concrete and road material.

The quartzite at the top of the Marburg schist has been quarried 1½ and 2½ miles southwest of Red Lion, and 1½ miles southeast of Red Lion. It was also quarried, probably for bridge piers, half a mile northwest of Brodbeck. The Antietam quartzite has been quarried for building stone at localities 1 mile, 2 miles, and 3 miles south of Pennsville, in the western part of the Hanover quadrangle. It has been quarried also, probably for road material, near the head of West Branch of Codorus Creek southeast of Krentler School, and near Cold Spring 1½ miles northeast of Jefferson.

Limestone has been used for building foundations, bridge piers, walls, and stone fences; and in pioneer

[41] Stose, G. W., Fairfield-Gettysburg folio, U. S. Geol. Survey Geol. Atlas, folio (No. 225), p. 20, 1929.

days, many houses were built of the limestone that was quarried locally.

Just south of Seitzland, metabasalt was quarried for bridge piers.

IRON ORE

Low-grade iron ore has been mined at many places in the area, but none has been taken out for many years. Most of the ore is residual limonite in the soil, and thorough washing is required to remove the clay and quartz. The ore is not of commercial grade at the present time. It is geologically significant, however, as many of the deposits are associated with limestone and suggests its presence where not exposed. In narrow valleys, where deep weathering and solution have resulted in a thick soil cover and there are no rock exposures, the presence of limestone is suggested by the iron ore. It also is commonly present along faults in limestone, where circulating water has brought the iron to the surface and deposited it in the soil.

The uppermost beds of the Antietam quartzite are very ferruginous, and iron ore accumulates as float in the soil overlying the Vintage dolomite at the foot of the dip slopes of hills composed of Antietam quartzite. Deposits of iron ore may be found, therefore, at most of the contacts of the Antietam quartzite and Vintage dolomite shown on the geologic map. Extensive deposits of this type have been mined on the borders of the Antietam quartzite on the southeast side of the Pigeon Hills from southwest of Mt. Carmel School northeastward nearly to Nashville. Iron ore similarly associated with the upper beds of the Antietam has been mined also south of Jacobs Mills, 1½ miles north and 1½ miles west of Spring Grove, and 1 mile northwest of Stonybrook.

Iron ore has been mined also where the Antietam quartzite is overlain by Conestoga limestone in the Jefferson syncline from Jefferson northeastward to and beyond Seven Valleys, in the syncline south of Margaretta Furnace, in the East Prospect syncline west of East Prospect, southwest of Klein School, south of Delroy, and in the syncline at Ore Valley.

Some of the iron ore deposits may have been concentrated by waters circulating along faults, especially those near the Iron Ridge and Smiths Station cross faults. Ore pits are associated with faults at localities 1½ miles west of Mt. Carmel School, southeast of Gnatstown, near Iron Ridge, at Hobart, and east of Nashville. Iron ore is associated with the Conestoga limestone near the Stoner overthrust east of York Road and in the valley at Penn Grove and south of Iron Ridge. Iron ore was formerly mined at the contact of the Wakefield marble and the Marburg schist northeast of Loganville.

Crystals of magnetite up to an eighth of an inch in diameter are scattered through some of the ferruginous quartzites of the Chickies slate, Harpers phyllite, and Wissahickon formation and in the metabasalt. In places the magnetite is more concentrated, and residual masses of good magnetite ore may be found in fields adjacent to the outcrops of these rocks, but no ore of commercial value has been developed. A pit 1 mile north of Strickhausers, in ferruginous quartzite of the Harpers phyllite, is the only place where magnetite is known to have been prospected in the area.

OIL AND GAS

Neither oil nor gas are to be expected from rocks in this area, but a well was drilled for oil on the top of a hill east of York New Salem. The well was sunk on an anticline of quartzite in the Chickies slate, north of the road running east and half a mile east of the crossroads. No oil was obtained and the well was abandoned.

WATER SUPPLY

The city of York requires a large quantity of water for its population and extensive industries. A bountiful supply of pure, soft water is obtained from Codorus Creek in the hills south of the city. A dam on the East Branch of Codorus Creek, 1 mile west of Jacobus, ponds the large body of water called Lake Williams, the upper end of which reaches to the highway (U. S. 111). The slopes of the hills surrounding the lake are protected from soil erosion by a dense growth of evergreens. The pumping and filtration plant is located farther down East Branch. A distributing reservoir on Violet Hill, 1½ miles south of York, is more than 200 feet above the city.

Hanover has a reservoir at several large springs in a ravine on the south side of the Pigeon Hills 1 mile east of State Highway 194. This water supply was not adequate for the growing industries of the city, and a larger quantity of soft water is now obtained from the Shepard Morris reservoir, 5 miles south of the city, where a dam, 1 mile southwest of Bandanna, ponds the water of the South Branch of Conewago Creek. Evergreen trees were planted in 1937 on the slopes of the hills in the vicinity of this reservoir.

Red Lion and Dallastown have a reservoir near the headwaters of Cabin Creek, just below Locust Springs. A small distributing reservoir is located on the hill southeast of Dallastown. Spring Grove obtains its water from Codorus Creek, which is ponded southwest of the town. The Glatfelter paper mill in Spring Grove drilled several wells in the valley south of the town in 1936 and 1937 to obtain an adequate supply of pure, soft water, and constructed a new reservoir just below the Hanover road.

Some of the small villages obtain their water from small reservoirs on nearby streams, but most of the smaller settlements depend on individual wells.

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