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GEOLOGY AND MINERAL RESOURCES OF THE MIDDLETOWN QUADRANGLE, PENNSYLVANIA

BY

GEORGE W. STOSE

AND

ANNA I. JONAS

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CONTENTS

ILLUSTRATIONS

GEOLOGY AND MINERAL RESOURCES OF THE MIDDLETOWN QUADRANGLE, PENNSYLVANIA

By George W. Stose and Anna I. Jonas

ABSTRACT

The Middletown quadrangle, in southeastern Pennsylvania, comprises parts of Lebanon, Dauphin, Lancaster, and York Counties, and is crossed by southwestward-trending belts of metamorphosed pre-Cambrian rocks, fossiliferous lower Paleozoic rocks, and Triassic sediments. The Chickies Ridge and the Hellam Hills form a range that extends southwestward across the southern part of the quadrangle. They separate the York Valley on the south from the wider Mount Joy Valley on the north, which lies north of the Susquehanna River in Lancaster County. A belt of Triassic sediments 10 miles wide occupies the northwest half of the quadrangle and separates the Mount Joy Valley from the Cumberland-Lebanon Valley, a small part of which occupies the northwest corner of the quadrangle. On the basis of physiographic divisions, the quadrangle as far as the northwestern edge of the Triassic sediments belongs in the Piedmont province. Geologically, the Mount Joy Valley north of the Hellam Hills is continuous with the Cumberland-Lebanon Valley, as they are underlain by Paleozoic limestones; and were it not for the presence of the younger unconformable Triassic sediments, they would together form one great limestone valley. The Hellam Hills and Chickies Ridge are anticlinal uplifts belonging with those of the Catoctin-Blue Ridge anticlinorium, to the west, from which they are separated by the Triassic sediments. The York Valley is a synclinal fold of Paleozoic limestones with a sequence slightly different from that of the Mount Joy Valley north of the Hellam anticline.

The Hellam Hills, which are the southwestern extension of Chickies Ridge on the Lancaster side of the Susquehanna River, bring to the surface metamorphosed pre-Cambrian volcanic rocks of both basaltic and rhyolitic character, which are well exposed in a rocky gorge leading to the river at Accomac and in the hills to the southwest. The Lower Cambrian arenaceous strata, with thick, coarse pebbly conglomerate beds near the base, unconformably overlie the pre-Cambrian core of the anticline and are about 2,000 feet thick. They dip south and southwest under calcareous and dolomitic rocks that range in age from Lower Cambrian to Ordovician. On the northwest side, along the Susquehanna River, the rocks of the Hellam Hills are thrust northwest over limestones which form the Mount Joy Valley, north of the river. The Chickies quartzite makes the noted cliff called Chickies Rock, where the Susquehanna has cut a narrow gap through the anticline, and forms cliffs, in places 150 feet high, along the river on the north edge of the thrust block, south of Marietta. The cliffs are breached by several rocky gorges with waterfalls of much natural beauty.

In early Ordovician time, in the area south of the Hellam Hills, the rocks were gently folded and lifted above sea level, and across their eroded edges the argillaceous Conestoga limestone, of probable Chazy age, was laid down. North of the Hellam Hills limestone sedimentation continued through the Ordovician until the end of Beekmantown time, when the Cocalico shale, of Trenton and Utica age, was deposited. No younger Paleozoic sediments are preserved in this area.

Late in Paleozoic time the region underwent folding and thrust faulting which affected the Appalachian area from New York to Alabama. The pre-Cambrian and Paleozoic rocks were closely folded, and many of the anticlines were broken on their north limbs and thrust northwestward over adjoining synclines.

After this folding and mountain making the area suffered erosion until the beginning of the Triassic period, when large blocks settled along nearly vertical tension breaks, and a basin was formed with a highland to the south of it that furnished sediments for the rocks of the Newark group. Later these rocks were tilted northwestward and were intruded by sheets and dikes of diabase, which, together with their borders of baked shale, form ridges in the northern part of the area.

Post-Triassic history is chronicled in the physiography, which gives evidence of progressive but intermittent uplifts, now preserved in remnants of high-level surfaces and gravel-covered terraces at lower levels bordering the river.

The mineral resources of the area comprise limestone, clay for brickmaking, sandstone, baked shale for road material, sand, and gravel. The limestone and clay are the most valuable. The limestone is quarried for high-calcium, low-silica limestone, low-silica dolomite, and crushed stone. The largest plants are near Rheems and on both sides of the Susquehanna River at Saginaw and Billmeyer, all of which are situated on the lines of the Pennsylvania Railroad. Clay derived from Triassic shale is used in brick plants at Royalton and Waltonville. The mining of iron ore and quarrying of red Triassic building stone (brownstone) were once flourishing industries in the area.

The Susquehanna River, which crosses the quadrangle, is the largest water-power stream in the eastern United States and has been utilized for hydroelectric development from Middletown southward. Municipal water supplies of the towns of the area are derived from surface water, ground water, and springs.

INTRODUCTION

Location of the area.—The Middletown quadrangle is in southeastern Pennsylvania and contains parts of York, Lancaster, Dauphin, and Lebanon Counties. (See fig. 1.) It is a rectangular area of 234 square miles between parallels 40° and 40° 15′ and meridians 76° 30′ and 76° 45′. The southwestern part of the area is crossed from northwest to southeast by the Susquehanna River, whose right bank forms the boundary line between York County on the southwest and Lancaster County on the northeast. More than one-third of the total area lies in Lancaster County and one-third in York County; the northern third is divided between Lebanon and Dauphin Counties. Middletown, a borough of 6,085 inhabitants, is in the northwestern part of the area at the junction of Swatara Creek with the Susquehanna River. The western part of Columbia, whose population is 11,349, lies within the quadrangle. Elizabethtown, with a population of 3,940, is followed in numbers by Mount Joy (2,716), Wrightsville (2,247), and Marietta (1,969). The smaller towns of Bainbridge, Rheems, Florin, Hellam, Emigsville, Mount Wolf, Pleasureville, and Yorkhaven each have populations between 500 and 1,000.

The central part of the area is crossed by the Philadelphia division of the Pennsylvania Railroad, which is a part of the main line between Philadelphia and Pittsburgh, and a branch line from

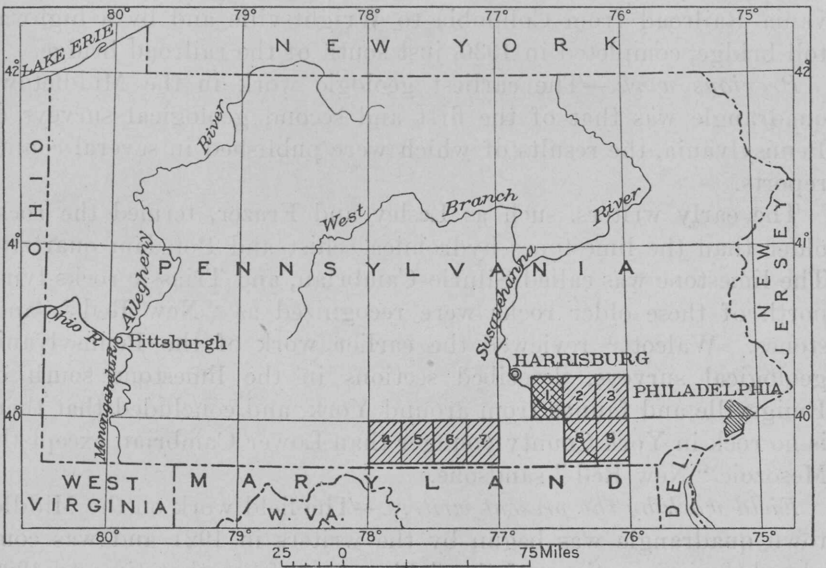

FIGURE 1.—Outline map of Pennsylvania, showing location of the Middletown quadrangle (1) and areas covered by other reports. Cooperative reports by Pennsylvania Geological Survey: 2, Pennsylvania Geologic Atlas, Lancaster quadrangle; 3, Pennsylvania Geologic Atlas, New Holland quadrangle. United States Geological Survey reports: 4–5, Mercersburg-Chambersburg folio; 6–7, Fairfield-Gettysburg folio; 8–9, Bull. 799, McCalls Ferry-Quarryville district

Lancaster to York crosses the Susquehanna at Columbia and the southeast corner of this area. The Columbia branch of the Pennsylvania Railroad runs along the left bank of the Susquehanna River from Middletown to Columbia. The Atglen and Susquehanna branch follows the left bank from Columbia to a point a mile west of Shocks Mills, where it crosses the river, and follows the right bank to the western edge of the quadrangle. This line carries only freight and is locally known as the "low-grade freight line" because it maintains a maximum grade of 5 feet to the mile between Philadelphia and Harrisburg. A branch of the Pennsylvania Railroad from Baltimore to Harrisburg runs north in the western part of the quadrangle. The Cornwall and Lebanon branch of the main line extends northeastward from Conewago Junction. The Philadelphia & Reading Railroad enters the quadrangle at the north from Hummelstown and follows Swatara Creek to Middletown.

Two branch lines of the Conestoga Traction Co. of Lancaster enter the area north of the Susquehanna River; one passes through Columbia and terminates at Marietta, and the other runs through Mount Joy to Elizabethtown. The Hershey Traction Co. has a line from Elizabethtown to Hershey, north of this area. The York Railways operate electric lines from York to Wrightsville and from York to Emigsville, Manchester, and Yorkhaven.

The Susquehanna River is crossed by a bridge of the Pennsylvania Railroad from Columbia to Wrightsville and by a highway toll bridge, completed in 1930, just south of the railroad bridge.

Previous work.—The earliest geologic work in the Middletown quadrangle was that of the first and second geological surveys of Pennsylvania, the results of which were published in several county reports.

The early writers, such as Lesley and Frazer, termed the rocks older than the limestones hydromica schist and Potsdam quartzite. The limestone was called Silurio-Cambrian, and Triassic rocks lying north of these older rocks were recognized as "New Red" sandstones. Walcott[1] reviewed the earlier work of the Pennsylvania geological surveys, described sections in the limestone south of Emigsville and faunas from around York, and concluded that there is no rock in York County younger than Lower Cambrian except the Mesozoic "New Red" sandsone.

Field work by the present writers.—The field work on the Middletown quadrangle was begun by the writers in 1921 and was completed during portions of the field seasons from that time to 1929. The work was done in cooperation with the Pennsylvania topographic and geologic survey, Mr. Stose representing the Federal Survey and Miss Jonas the State. As the result of much detailed study of the general region of Pennsylvania adjacent to the Middletown quadrangle the writers first published a section of the lower Paleozoic rocks of southeastern Pennsylvania.[2] This paper was followed by a description of the Ordovician unconformity and overlap in the same area.[3] Reports on quadrangles to the east and southeast of the Middletown area have already been published.[4]

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

[2] Stose, G. W., and Jonas, A. I., The lower Paleozoic section of southeastern Pennsylvania: Washington Acad. Sci. Jour., vol. 12, pp. 358–366, 1922.

[3] Stose, G. W., and Jonas, A. I., Ordovician overlap in the Piedmont province of Pennsylvania and Maryland: Geol. Soc. America Bull., vol. 34, pp. 507–524, 1923.

[4] 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.

SURFACE FEATURES

Surface forms.—The Middletown quadrangle is part of the physiographic division of the eastern United States that is known as the Piedmont province. A small area in the northwest corner is part of the Appalachian Valley and Ridge province. The surface forms of the area fall into three distinct types—(1) a well-dissected upland forming the Hellam Hills and Chickies Ridge and cut through by the Susquehanna River at Chickies Rock (see pl. 2, *A*) and a small portion of another upland in the extreme southeastern part of the area; (2) a lowland that forms the narrow York Valley and a wider valley north of the Hellam Hills and Chickies Ridge, which may be called the Mount Joy Valley; (3) the north half of the area, north of the Mount Joy Valley, which is in general a lowland with long low ridges and a few round hills that rise abruptly above the general surface.

The York Valley is a well-developed narrow valley extending southwestward from Columbia and is controlled in shape and extent by the underlying rocks, limestone and dolomite. It is a part of a larger valley that extends from the vicinity of Philadelphia through the Chester, Quarryville, and Lancaster Valleys to York and Hanover. In the Middletown quadrangle the valley floor is flat and about a mile wide. It is crossed by a succession of small runs that flow southward into Kreutz Creek, which flows eastward along the south side of the valley into the Susquehanna River. The bounding ridges on the north and south rise steeply above the valley.

Altitude.—The highest parts of the area are in the Hellam Hills and in the hills east of Middletown. The highest point in the Hellam Hills is 1,040 feet above sea level, 2½ miles west of Highmount. The ridge just west of Highmount and that south of Glades attain 900 feet, and Roundtop, opposite Marietta, 800 feet. The Hellam Hills slope steeply to the Susquehanna on the north and less steeply to lower hills on the south and west. The hills south of the York Valley rise to 700 feet in this area, and those west of Codorus Creek and north of the Emigsville Valley have an average altitude of a little over 600 feet. The range of hills in the northwestern part of the area, east of Middletown, has its highest point in Roundtop, 940 feet; Allen Mountain and a hill east of Roundtop reach 800 feet; and the general altitude for other hills is 700 feet. The ridge that extends southwestward from Colebrook to Falmouth rises to 700 feet at its northeast end; at the southwest its general summit altitude is around 600 feet.

The rest of the quadrangle is a rolling lowland with an average summit level of 400 feet. This lowland comprises the York and Mount Joy Valleys, the valleys of both Conewago Creeks, one on each side of the Susquehanna River, and the valley of Swatara

Creek. The level of the Susquehanna River at Middletown is about 280 feet; at Columbia, 18 miles to the southeast, it is 227 feet.

Drainage.—The quadrangle is drained by the Susquehanna River and its numerous tributaries. The Susquehanna, which crosses the area from northwest to southeast for a distance of 20 miles, has its source in Lake Otsego, N. Y. From its source to its mouth, at the head of Chesapeake Bay, it is 422 miles long and drains an area of 27,400 square miles. The portion that is included in this quadrangle lies 360 miles from its source and 25 miles from the mouth and has an average fall of 3 feet to the mile. Its course is broken by waterfalls and rapids where it flows over hard rock, and at such places it is much narrower than elsewhere because of the resistance of the hard rock to corrasion. Its width is therefore irregular. From a width of 1¾ miles south of Middletown it narrows to half a mile at Conewago Falls, where the diabase sheet and associated baked shale, which extends southwestward from Falmouth, bar its way. A diabase dike near Billmeyer produces the Haldeman Riffles. (See pl. 9, *B*.) The narrowest place in the Susquehanna is between Chickies Rock and Hellam Point, where the river flows in a gorge less than half a mile wide. (See pl. 2, *B*.) Ledges of the hard quartzite, which forms the barrier, cross the river here, and ledges of other hard rocks crop out for a mile to the south and produce a series of falls extending nearly to Columbia, where the river again widens. The larger streams that flow into the Susquehanna, most of which have their sources outside the Middletown quadrangle, are Swatara, Chickies, Conewago (York County), Conewago (Lancaster County), and Codorus Creeks. Swatara Creek flows 5 miles southward across the northwest corner of the quadrangle and empties into the Susquehanna at Middletown. The southern Conewago Creek (York County) divides at the flood plain of the river, 2 miles south of Yorkhaven, and one stream flows north, the other south on the west side of an island which is the delta of the stream. The northern outlet enters the Susquehanna River at Yorkhaven and the other at Saginaw, 3½ miles to the southeast. There is a minor outlet across the island. Codorus Creek, which heads near the Maryland line, flows northeastward in a winding course across 6 miles of the area. Chickies and Little Chickies Creeks unite 1½ miles above the Susquehanna at Chickies. Upper reaches of Little Chickies Creek drain the eastern part of the area. The northern Conewago Creek forms the boundary line between Lancaster and Dauphin Counties and heads in Lebanon County just beyond the north boundary of the Middletown quadrangle. It flows for 15 miles across the quadrangle into the Susquehanna River at Falmouth. The altitude at its source is 700 feet and at its mouth 275 feet, a fall of 425 feet in 30 miles. Conoy Creek rises east of Elizabethtown in Mount Joy Township and flows in a southerly course into the Susquehanna about a mile below Bainbridge. Donegal Creek is another small stream 15 miles long whose drainage basin lies wholly in the quadrangle. It heads east of Elizabethtown and enters Chickies Creek near the mouth, with a total fall of 150 feet. Kreutz Creek flows northeastward on the south side of the York Valley for 5 miles within the quadrangle, between Stoner Station and Wrightsville. Its sources are to the south within the York quadrangle and in the south face of the Hellam Hills.

AREAL GEOLOGY

The quadrangle contains rocks of both sedimentary and igneous origin. The Hellam Hills are composed of the oldest rocks of the area, comprising pre-Cambrian lava flows overlain unconformably by Lower Cambrian conglomerate, quartzite, and slate, resistant rocks that cause these hills and Chickies Ridge to stand up above the surrounding country. Another ridge of Lower Cambrian quartzite and slate lies south of the York Valley, which is underlain by limestones—rocks that are softer and more easily dissolved. Another larger limestone valley lies north of the Hellam Hills and southeast of the wide area of red Triassic sediments that covers the northern two-thirds of the quadrangle. The Triassic rocks consist of conglomerates, sandstone, and shale intruded by sheets or sills of diabase. Diabase was also forced into long vertical fissures, forming dikes, which are now exposed at the surface cutting the older rocks as well as the Triassic sediments. A small area of limestone which is part of the larger Lebanon Valley, to the north of the Middletown quadrangle, occurs in the northwest corner of the quadrangle, on the north side of the Triassic rocks.

The older rocks of the area, pre-Cambrian, Cambrian, and Ordovician, are in most places steeply inclined and are folded into long, wide troughs or synclines and narrower arches or anticlines that trend southwestward. The oldest rocks, of pre-Cambrian age, are exposed only in the core of the anticline of the Hellam Hills. This anticlinal uplift extends eastward through Chickies Ridge into Chestnut Hill, in the Lancaster quadrangle, and is in strike with the anticlinal uplift of the Honeybrook upland in and east of the New Holland quadrangle.[5] These folds belong with those of the New York and New Jersey Highlands uplift and the Catoctin-Blue Ridge anticlinorium, and as such are part of the Appalachian Mountain structure. (See pl. 11.) They are separated from the northern part of this anticlinorium, which includes in Pennsylvania the Reading Hills, Catoctin Mountain, and South Mountain uplifts, by synclinal infolds of younger Paleozoic rocks and by down-faulted Triassic rocks.

[5] Jonas, A. I., and Stose, G. W., Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas, No. 178, p. 9, 1926.

The pre-Cambrian rocks of the Hellam Hills are metamorphosed lavas similar to those that form the pre-Cambrian basement of the South Mountain-Catoctin Mountain anticlinorium, to the southwest, west of the belt of Triassic rocks that crosses the Middletown quadrangle. The pre-Cambrian rocks of the Honeybrook upland and of the Reading Hills, to the northeast, comprise metamorphosed pre-Cambrian sediments that are intruded by igneous rocks ranging in composition from granite to gabbro. The basic pre-Cambrian volcanic rocks are not exposed in any of the uplifts of the anticlinorium in Pennsylvania northeast of the Susequehanna River.

The sequence and character of the formations that crop out in the quadrangle are given in tabular form in Plate 3.

PRE-CAMBRIAN ROCKS (ALGONKIAN?)

ROCKS OF IGNEOUS ORIGIN

The pre-Cambrian rocks of the Middletown quadrangle occur in two anticlinal areas southwest of Accomac. The northern area extends for 2 miles along the axis of the anticline and has a narrow branch on the south side of a minor syncline north of Highmount. It is surrounded by the overlying basal Cambrian sediments, the Hellam conglomerate member of the Chickies quartzite, except where that conglomerate is faulted out on the southeast side of the anticline. The southern area is smaller than the one near Accomac, being less than 2 miles long along the axis of the fold and half a mile wide. It is overlain by Hellam conglomerate on all sides except where bounded by normal faults.

The effusive rocks of these pre-Cambrian areas comprise aporhyolite and metabasalt; in the southern area slates of probable tuffaceous origin are included. These effusive rocks were once bedded lavas containing open vesicles and having flow banding and other structural features that commonly occur in lavas. Pressure and heat developed by the load of sediments under which they were buried after extrusion, accompanied by lateral pressure in the presence of hot water, have changed the texture of the lavas to crystalline rocks in which few of the original minerals remain. The floor upon which these lavas were poured out is not exposed in Pennsylvania or Maryland, so far as known, but is probably composed of pre-Cambrian crystalline schists and igneous rocks similar to the Lynchburg gneiss and Lovingston granite gneiss, on which the pre-Cambrian lavas of the same anticlinorium were extruded to the southwest in Virginia.

METABASALT

Metabasalt occurs in a small area just north of Highmount and in a larger area extending for a mile along the valley of the small stream leading to the Susquehanna River at Accomac. Many good exposures are found in the gorge of this stream all the way to its mouth. Metabasalt not so well exposed also occurs in the western part of the southern pre-Cambrian area 1½ miles northwest of Hellam. The metabasalt, or "greenstone," as it is commonly called, is a grayish-green to bluish-gray hornblende schist, blotched with green epidote, which forms knots on the weathered surface. Some massive layers are spotted with light-green or white amygdules filled with quartz, or calcite, or epidote with chlorite lining. Where the amygdular filling has been dissolved by weathering, the rock is pitted or porous and has a "worm-eaten" appearance. The constituents of the metabasalt are epidote, hornblende, chlorite, quartz, feldspar, and magnetite. All are secondary minerals—that is, they crystallized after the original lava was poured out and solidified. Flow banding is still visible in the more massive varieties. The fine-grained parts of the flow have been altered to a schist in which the amygdules are drawn out and are now represented by flattened blebs. The rock has veins of secondary epidote and some asbestos, which is exposed just south of Accomac.

In thin section the massive "greenstone" is made up of a groundmass of albite, epidote, quartz, and magnetite with phenocrysts of feldspar and the green hornblende, uralite, some of which shows original augite cores. The amygdules are filled with hornblende, epidote, calcite, quartz, and albite. The albite feldspar of the groundmass is corroded by secondary hornblende and chlorite and is itself secondary to more calcic feldspar whose lime went to form epidote.

The original composition of the rock must be inferred from the composition of the secondary minerals that now compose it. It is thought that the original rock was probably a cryptocrystalline or even partly vitreous lava having the composition of a basalt. No analyses of the basic volcanic rock of the Middletown quadrangle are available, but the following analysis represents rock from the pre-Cambrian area of South Mountain, Pa., which it is believed was continuous with the basement of the Hellam Hills in pre-Cambrian time.

Analysis of metabasalt from Bechtel copper shaft, South Mountain[6]

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

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

APORHYOLITE

Aporhyolite occurs in the Accomac anticline and in the eastern part of the Mount Zion anticline (p. 50). In general it is a fine-grained hard, dense rock with or without phenocrysts of feldspar and quartz. The original glassy base has been altered to a finely crystalline mosaic of quartz and feldspar. In some varieties flow banding is preserved on weathered surfaces of the rock. It varies in color from bluish gray to purple, red, or dark gray.

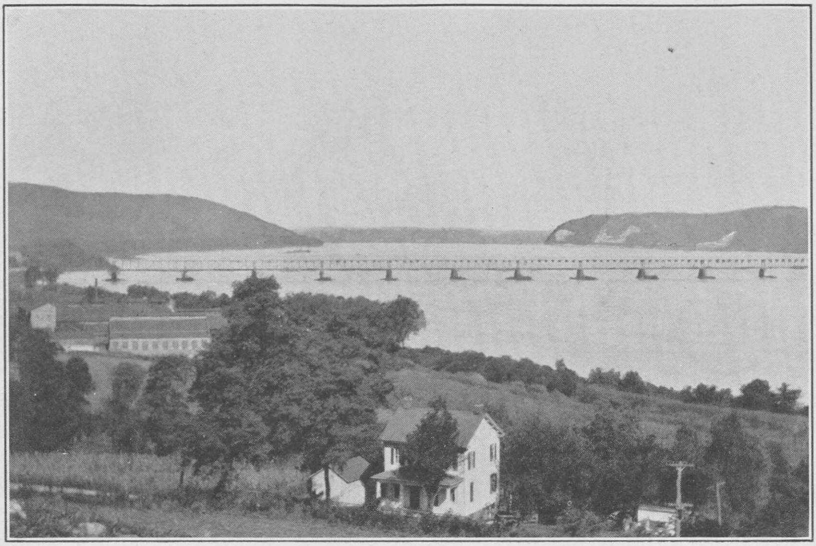
In the Accomac anticline are exposed two varieties of aporhyolite, a blue-gray fine-grained rock and a purple rhyolite porphyry. The purple variety is exposed only in the southwestern part of the area. It is separated by a white quartz vein from the blue-gray aporhyolite north of it, which forms most of the aporhyolite of the anticline. A zone of brecciated aporhyolite occurs in the blue aporhyolite and extends across it for 1¾ miles from the western edge N. 45° E. to the river. It is exposed in places on a secondary road half a mile north of Highmount, where it occurs in two areas each 50 to 75 feet wide, separated by fine-grained blue aporhyolite. The breccia is very striking in appearance because it is made up of various sized angular fragments of pink aporhyolite cemented by blue quartz and finely crushed aporhyolite. The fragments are broken and are penetrated by the blue quartz, with which there is abundant black ilmenite. The breccia contains also some epidote-quartz veins.

In thin section the pink aporhyolite shows euhedral feldspar in a fine quartz matrix and spherulites of quartz in radiating bundles. It contains also zircon, secondary sericite, and iron. Iron is present in the form of hematite and gives the pink color to the rock. The secondary quartz that cements the fragments and penetrates them in cracks is finely granulated.

The fine-grained blue aporhyolite in which the breccia occurs is similar to the pink variety in texture and also contains spherulites. The iron is present as small particles of magnetite. The pink color of the breccia may be due to the fact that the hot waters which brought in epidote, quartz, and ilmenite altered the iron of the aporhyolite from magnetite to hematite. Similar change in color has been reported by Stose [7] from South Mountain, where blue aporhyolite is altered to pink on the edges of quartz-epidote veins.

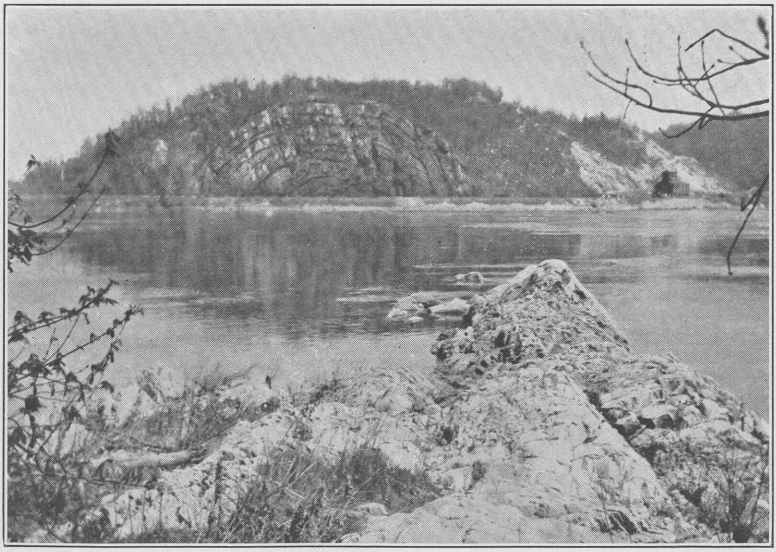
The pink breccia differs from a flow breccia in that the matrix is largely blue quartz and not aporhyolite, and the rock of which the breccia is composed consolidated without flowage, as is seen from

[7] Mineral resources of Adams County, Pa.; Pennsylvania Geol. Survey, 4th ser., Bull. C 1, pt. 2, pp. 23, 51, 1925; U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), p. 12, 1929.



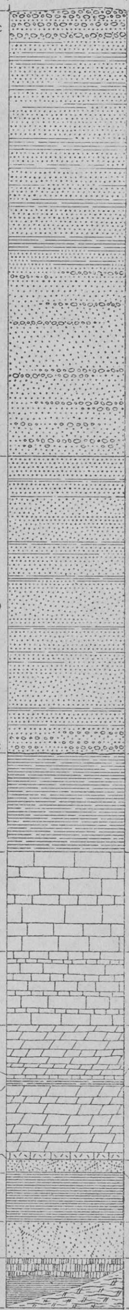
A. SUSQUEHANNA GAP AT CHICKIES ROCK

Looking upstream from a point below Wrightsville. Hellam Point, headland at left of gap; Chickies Rock, cliff at right of gap. Pennsylvania Railroad bridge at Columbia.

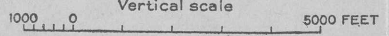


B. CAMBRIAN QUARTZITE LEDGES IN FOREGROUND AT HELLAM POINT AND MAKING RIFFLES ACROSS THE RIVER TO CHICKIES ROCK

The anticlinal attitude of the quartzite in Chickies Rock is well shown.



System	Group	Formation	Symbol	Thickness (feet)	Character of rocks
Triassic	Newark group	Gettysburg shale, with conglomerate member, TRgc, at and near top.	TRgc TRg	9,000	Soft red sandstone and shale with some conglomerate beds. Heavier conglomerate beds, TRgc, at top. Metamorphosed to hard purplish-black porcelanite adjacent to intrusive diabase.
		New Oxford formation, with limestone conglomerate, TRlc, and quartzose conglomerate, TRqc, at base.	TRno TRlc TRqc	6,000	Light-gray to grayish-yellow arkosic crumbly sandstone with interbedded thin red to purplish shale and sandstone; some hard quartzose conglomerate and limestone conglomerate near base. Disintegrates to sand and gravel, which is in places dug for building sand. Metamorphosed to hard rocks adjacent to intrusive diabase.
		Unconformity.			
Ordovician		Cocalico shale. (Conestoga limestone occupies part of this interval in southern part of area.)	Oc	2,000	Gray argillaceous shale, black in places; near base red, purple, and green shale, probably in part volcanic ash, and in places containing thin layers of hard platy sandstone. (Conestoga limestone, about 2,000 feet, unconformable on rocks from Beekmantown limestone to Vintage dolomite. Thin-bedded blue limestone, generally closely folded, and gray granular limestone with slaty partings; coarse limestone conglomerate, sandstone, and black slate, at base in most places.)
		Beekmantown limestone.	Ob	2,000	Pure blue limestone, laminated light-blue magnesian limestone, and lenticular gray dolomite veined with calcite and quartz; contains some black chert.
Cambrian		Conococheague limestone. (Elbrook limestone probably present but not recognizable.)	Єcg	1,500	Light-gray limestone banded with siliceous and argillaceous layers, dolomite, and fine-grained white marble; contains *Cryptozoon* reefs.
		Ledger dolomite.	Єl	1,000	Light-gray pure granular dolomite with some rough-weathering chert. Weathers to deep-red granular soil.
		Kinzers formation.	Єk	150	Dark shale below; blue-banded limestone and white-spotted marble above.
		Vintage dolomite.	Єv	1,500	Dark-blue knotty dolomite with impure white marble at base.
		Antietam quartzite.	Єa	200	Gray quartzite with granular ferruginous fossiliferous quartzite at top.
		Harpers phyllite.	Єh	1,000	Grayish-green phyllite and dark and white banded sericitic slate.
		Chickies quartzite.	Єc	550-1,000	Massive white *Scolithus*-bearing quartzite and quartz schist with sericitic partings; basal Hellam conglomerate member, 500 feet maximum.
Pre-Cam. (Alg?)		Metabasalt. Volcanic slate. Aporhyolite.	mb vs ar		Altered basalt and rhyolite lavas and volcanic slate.



COLUMNAR SECTION OF THE SEDIMENTARY ROCKS OF THE MIDDLETOWN QUADRANGLE the texture and the presence of spherulites. The breccia is probably a fault breccia or zone of crushing in the blue rhyolite and may have occurred in the pre-Cambrian because neither the blue quartz veins nor the ilmenite has been found to extend into the Lower Cambrian Hellam conglomerate near by. The blue quartz veins have been granulated during a later period of pressure.

The purple aporhyolite porphyry of the southern part of the Accomac anticline is best exposed in the small quarry of A. Fabringer, half a mile north of Highmount. It is a dark-purple rock with phenocrysts of pink feldspar and quartz.

The aporhyolite of the Mount Zion anticline is also a porphyry but is of a dark slate-gray color, with light-gray glassy feldspar and quartz phenocrysts, which in thin sections are seen to be cracked and veined with quartz. The groundmass of quartz and feldspar is fine-grained, with thin blades of sericite; particles of magnetite cover the rock like dust. Near the south edge of the exposure there is light-blue aporhyolite which has been crushed. Green muscovite is developed on the cleavage planes.

Similar aporhyolite occurs in wide areas in the Catoctin Mountain-South Mountain anticlinorium of southern Pennsylvania and Maryland, and two analyses of aporhyolite from that locality are given below.

Analyses of aporhyolite from South Mountain, Pa.

	1	2		1	2
SiO_2	76.34	73.85	H_2O+	0.10	0.71
Al_2O_3	11.60	13.15	H_2O-	.39	
Fe_2O_3	2.41	3.27	TiO_2	.26	
FeO	.30	.36	CO_2	Trace.	
MgO	.06	.32	P_2O_5	Trace.	.06
CaO	.55	.82	MnO	Trace.	.09
Na_2O	5.50	2.29	BaO	.09	
K_2O	2.75	5.42			
				100.35	100.34

1. Aporhyolite, Monterey, Franklin County, Pa. H. N. Stokes, analyst, U. S. Geol. Survey Bull. 150, p. 348. 1898.
2. Quartz porphyry, same locality. L. G. Eakins, analyst. U. S. Geol. Survey Bull. 148, p. 81, 1897.

VOLCANIC SLATE

The western part of the southern pre-Cambrian area contains blue slate and spotted slate associated with epidotic greenstone schist (metabasalt). The blue rock is a dark purplish, sparkling sericitic slate, some of which contains flattened amygdules. In places it is banded with green chlorite. Sericite and hematite make up the bulk of the rock, and hematite occurs in dustlike particles that give it a bluish color. It seems probable that the original material was a volcanic tuff of rhyolitic composition. Slate with similar constituents and association is widespread in Carroll and Frederick Counties, Md., and analyses [8] show that the potash content is from 4.16 to 6.02 per cent and the silica, lime, and magnesia content is low. This chemical composition relates it to the rhyolite rather than to the metabasalt.

AGE OF THE VOLCANIC ROCKS

The volcanic rocks of the Middletown quadrangle are pre-Cambrian, because they are overlain unconformably by Lower Cambrian sedimentary rocks. They are considered to be of later pre-Cambrian age. No intrusive relations between the aporhyolite and the metabasalt that would show which is the older have been observed in the quadrangle. In the Catoctin Mountain-South Mountain uplift the rhyolite flows are considered older than the basaltic lavas.[9]

CAMBRIAN SYSTEM

CHICKIES QUARTZITE

Distribution.—The Chickies quartzite is the oldest sedimentary formation exposed in the Middletown quadrangle. It has a prominent basal member, the Hellam conglomerate, which underlies the quartzite proper.

The formation is exposed in the Middletown quadrangle north of the York Valley, where it forms the high Hellam Hills, which extend from Mount Zion, at the south boundary of the quadrangle, northeastward to the river, with their eastern crest in Roundtop. Across the river it forms the noted cliff called Chickies Rock and Chickies Ridge. A still higher and more prominent quartzite hill, also part of the Hellam Hills, extends westward along the river to Codorus Creek.

Character and thickness.—The Chickies quartzite is largely a massive quartzite, with a subordinate amount of dark and banded slate and a heavy quartzose conglomerate interbedded with slate at the base. A generalized section of the Chickies quartzite north of the York Valley is as follows:

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[8] Mathews, E. B., and Grasty, J. S., Report on the limestones of Maryland: Maryland Geol. Survey, vol. 8, pp. 355–395, 399, 1909.

[9] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey Fourteenth 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., Geology and mineral resources of Adams County, Pa.: Pennsylvania Topog. and Geol. Survey Bull. C 1, p. 30, 1932; U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), p. 4, 1929.

Generalized section of Chickies quartzite north of the York Valley

	Feet
Massive to thin-bedded hard white quartzite containing numerous *Scolithus* tubes and some dark slate in upper part	300–400
Hellam conglomerate member, composed of coarse and fine quartz-sericite conglomerate interbedded with white sericitic feldspathic quartzite and thin layers of green and purple banded quartzite and blue and green slate	250–600±
	550–1, 000±

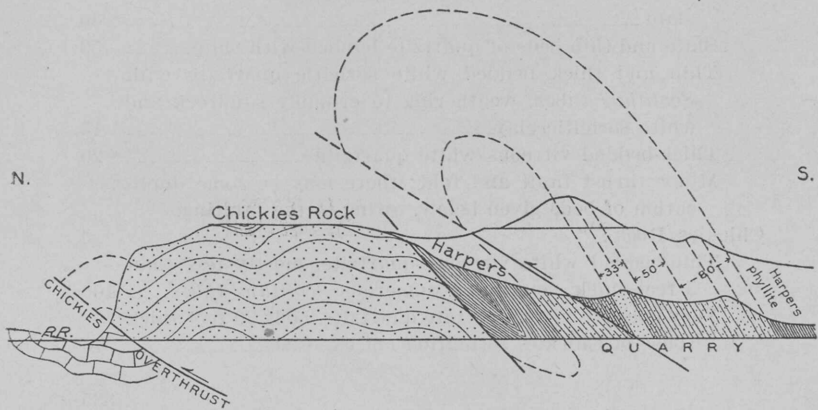


FIGURE 2.—Structure section at Chickies Rock. The higher beds of the Chickies quartzite, in the quarry to the south, are complicated by faulting

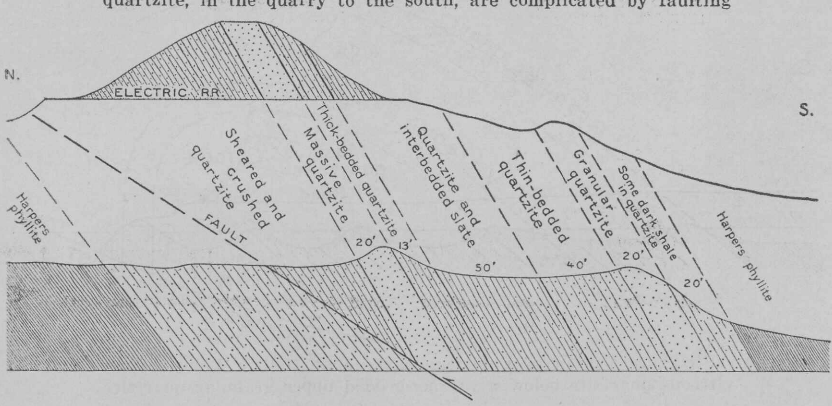


FIGURE 3.—Detailed section of upper part of Chickies quartzite at quarry south of Chickies Rock. The lower profile is the top of the quarry face; the upper profile is the top of the railroad cut

The quartzite of the formation is best exposed in Chickies Rock and adjacent cliffs on the Susquehanna River north of Columbia. A continuous section is not exposed, as the rocks are folded and faulted. The structure at Chickies Rock as interpreted by the writers is shown in Figure 2, and the details of the beds in the quarry to the south are shown in Figure 3.

A composite section made up from Chickies Rock and the quarry just south of it is as follows:

Composite section of Chickies quartzite at Chickies Rock

	Feet
Quarry just south of Chickies Rock:	
Grayish-green phyllite and slate (Harpers formation).	
Thin-bedded quartzite and interbedded thin dark slate	20
Thick-bedded white quartzite and coarse granular blue quartzite with grains of blue and dark glassy quartz and feldspar and small pebbles	20
White thin-bedded quartzite with interbedded thin dark slate	40
Slate and thin beds of quartzite banded with slate	50
Thin and thick bedded white sericitic quartzite with *Scolithus* tubes, weathering to crumbly sandrock and white sericitic clay	15
Thick-bedded vitreous white quartzite	20
Minor thrust fault and fold; there may be some duplication of beds given below, owing to the faulting.	
Chickies Rock:	
Thin-bedded white vitreous quartzite, mostly less than 5 feet thick, containing numerous *Scolithus* tubes	100
Very massive vitreous white quartzite, beds 20 feet thick (base of Chickies formation not exposed)	70
	335+

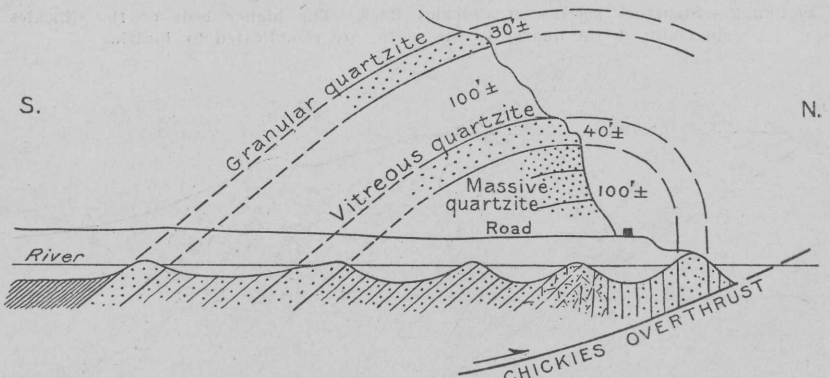


FIGURE 4.—Structure section of Chickies quartzite at Hellam Point. Shows massive vitreous quartzite below a thinner-bedded upper granular quartzite

The lower massive quartzite which makes the cliffs at Chickies Rock is folded into a double anticline. The schistosity, which dips 45° SE., is strongly developed on the north side of the ledge, where the beds are crushed because of their proximity to the thrust fault that lies just north of Chickies Rock. The upper beds of the section shown at the top of the quarry to the south are for the most part cut out at Chickies Rock by the minor fault on its south side. Another fault is exposed in the quarry. The rock of the quarry also has a marked southeasterly schistosity, which obscures folds in the thinner beds.

The section at Hellam Point, across the river from Chickies Rock, is not so clearly exposed, but the general sequence is the same. The section as interpreted by the writers is shown in Figure 4.

The massive lower beds of the Chickies quartzite form cliffs, in places 150 feet high, along the Susquehanna River from a point east of Dugan Run for 3½ miles westward. The most prominent cliffs are at Sholls Rock, near the low-grade bridge of the Pennsylvania Railroad. (See pl. 4, *A*.) The top of the bluff east of Dugan Run is formed by Hellam conglomerate, which here overlies the quartzite on the limb of a recumbent anticline. (See fig. 5.) West of Dugan Run the massive quartzite is exposed in several minor anticlines that are also overturned to the northwest. In the intervening synclines the upper thinner-bedded and granular quartzite of the Chickies comes to the river level and also forms the upland surface near the river. The anticlines are apparently recumbent minor folds which are broken on the under side and thrust northwestward and which join the Chickies overthrust in the river. (See fig. 13.) The rocky gorges in quartzite at Wildcat Falls and at the mouth of Trout Run are two of the most scenic spots in the area.

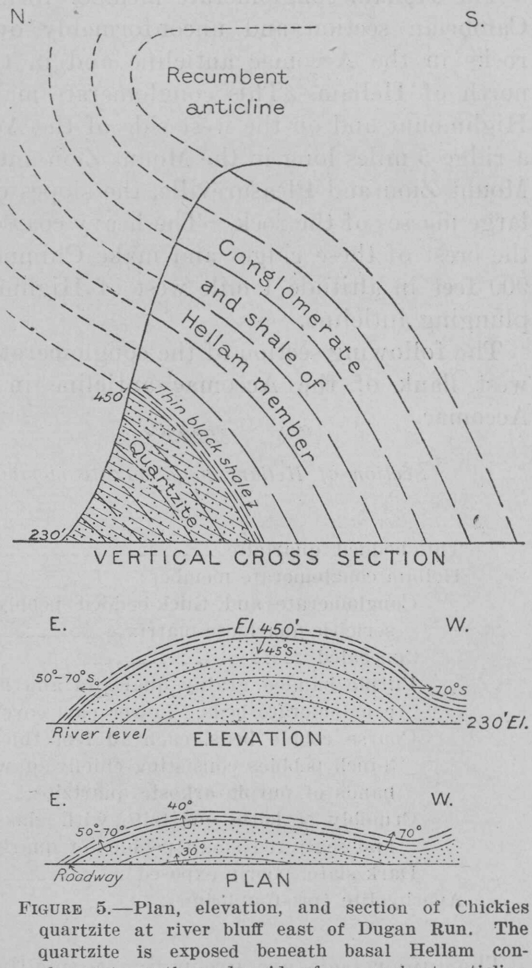


FIGURE 5.—Plan, elevation, and section of Chickies quartzite at river bluff east of Dugan Run. The quartzite is exposed beneath basal Hellam conglomerate on the under side of a recumbent anticline, as shown in the vertical cross section

The massive lower quartzite is exposed also in two anticlines northwest of Starview that are believed to be at the edge of the same overthrust mass near the point where it passes under Triassic sediments.

The massive lower quartzite crops out in places at the plunging southwest end of the Mount Zion anticline but is faulted out in part.

The Chickies quartzite occurs within the Harpers area in a faulted anticline near Highmount and in several sharp anticlinal folds along the river south of Roundtop and Chickies Rock. (See pl. 4, *B*.)

The Hellam conglomerate member forms the base of the Lower Cambrian section and unconformably overlies the pre-Cambrian rocks in the Accomac anticline and in the Mount Zion anticline north of Hellam. This conglomerate makes prominent hills near Highmount and on the west side of the Accomac Valley and forms a ridge 5 miles long in the Mount Zion anticline, extending through Mount Zion and Pleasureville, the slopes of which are strewn with large masses of the rock. The heavy coarse conglomerate beds form the crest of these ridges and make Chimney Rock, a high pinnacle 900 feet in altitude 1 mile west of Highmount, on the crest of the plunging anticline.

The following section of the conglomerate is exposed on the northwest flank of the Accomac anticline in the river bluff west of Accomac.

Section of Hellam conglomerate member west of Accomac

	Feet
Thin-bedded quartzite	20
Hellam conglomerate member:	
Conglomerate and thick-bedded pebbly quartzite with sericitic quartzose matrix	40
Concealed	200±
Purple banded grainy quartzite and many pebbly and conglomerate beds. Lower part covered	200±
Coarse cobble beds, each 10 feet thick, with rounded 3-inch pebbles consisting chiefly of white quartz, and bands of purple arkosic quartzite	40±
Crumbly sericitic quartzite with glassy quartz grains and scattered small pebbles of quartz	100±
Dark slate, poorly exposed	20±
Aporhyolite (pre-Cambrian).	
	600±

The upper beds are green fine to medium-grained sericitic feldspathic quartzite, containing pink and white feldspar with the quartz grains and pebbles, interbedded with blue and black slate and fine white granular feldspathic quartzite. The coarse conglomerate is composed of cobble beds each 10 feet thick, with pebbles 3 to 6 inches long in a finer quartz-sericite matrix that cements the pebbles. (See pl. 5.) The cobbles are well rounded and are composed for the most part of milky-white quartz; some are red and black jasper and quartzite with black hornblende needles. There are beds of purple and green fine conglomerate with a dark-green quartz-sericite matrix, blue and clear glassy quartz grains and small pebbles, and green angular quartzite fragments. At the base there are thin beds of sparkling green or blue slate with fine quartzose layers, fine banded magnetite-bearing quartzite with glassy quartz grains and green and black bands 2 inches wide.

The maximum thickness of the Hellam conglomerate member in the type locality is 600 feet. The conglomerate is variable in thickness, however, and 15 to 20 miles to the east, in the Mine Ridge anticline and in Welsh Mountain, it is much thinner, probably less than 100 feet. It is approximately equivalent to the Loudoun formation of Catoctin Mountain and South Mountain in southern Pennsylvania and to the basal conglomerate of the Cambrian quartzite in the Reading Hills.

Age and correlation.—The Chickies quartzite was named in 1878 by Lesley and Frazer from outcrops of quartzite in Chickies Rock. The quartzite is exposed in an anticline at the type locality, and the underlying Hellam conglomerate member is brought to the surface 2 miles to the west in the Hellam Hills, from which the member was named.[10] The Hellam conglomerate is the basal member of the Chickies quartzite. It contains no fossils. It unconformably overlies pre-Cambrian rocks throughout its extent and contains pebbles of blue quartz and slate derived from those rocks. The Chickies quartzite is conformably overlain by rocks which contain Lower Cambrian fossils, and it is therefore also of Lower Cambrian age.

CHICKIES SLATE

Distribution.—The equivalent of the Chickies quartzite that occurs south of the York Valley differs so much from the typical Chickies north of the valley that it is described separately under the heading Chickies slate. It makes prominent hills that extend from the river south of Wrightsville southwestward to Codorus Creek south of York, also similar hills across the Susquehanna, south of Columbia.

Character and thickness.—South of the York Valley the Chickies is a black slate interbedded with thin dark platy quartzite. It has been identified as the equivalent of the massive Chickies quartzite north of the valley because it overlies the Hellam conglomerate member and underlies the Harpers phyllite. It crops out in an anticline 1 mile south of Wrightsville, in the center of which the Hellam conglomerate member is exposed at the south edge of the quadrangle

[10] Stose, G. W., and Jonas, A. I., Lower Paleozoic section of southeastern Pennsylvania: Washington Acad. Sci. Jour., vol. 12, p. 360, 1922.

and extends southwestward 4 miles. The section of the Chickies slate in this area is as follows:

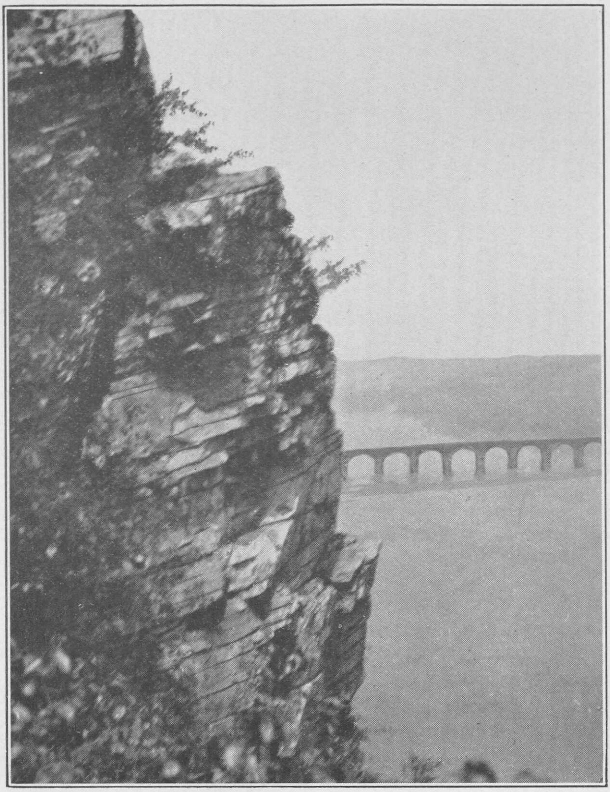
Generalized section of the Chickies slate south of the York Valley

	Feet
Very sandy phyllite (Harpers).	
Chickies slate:	
Black banded slate	50±
Thin slabby quartzite in slate (upper quartzite zone); 3-foot and thinner beds of green and dark ferruginous rust-spotted quartzite containing magnetite and weathering rusty	30±
Thin fissile black-banded crumbly slate with light quartzose banding and thin quartzite; weathers with a white coating	300±
Thin-bedded to massive white to bluish quartzite with thin partings of black slate (middle quartzite zone)	40
Black slate banded with light sandy layers and green quartz phyllite containing magnetite in places	150±
Quartzite, thick bedded and vitreous in middle, thinner bedded above, and white quartzite with slate partings below (lower quartzite zone)	60±
Dark-gray to black slate and green sandy phyllite, largely concealed	200±
Coarse sericitic quartzite and conglomerate beds in two ledges with crumbly gray quartzite between (Hellam conglomerate member)	60±
	890±

HARPERS PHYLLITE

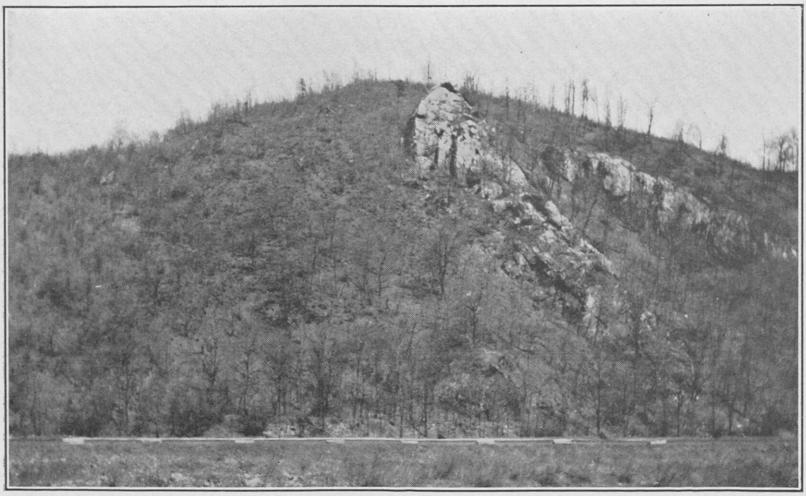
Distribution.—The Harpers phyllite conformably overlies the Chickies quartzite on both flanks of the Hellam Hills anticlinorium. It covers a large irregular area on both sides of the Trout Run anticline along Codorus Creek from a point near Glades to Starview. Another large area extends from the east side of the Susquehanna River north of Columbia southwestward, beyond Highmount. This area passes westward into a narrow faulted strip on the south flank of the Mount Zion anticline and around the southwestward plunging end of the fold at Pleasureville. At the head of Dugan Run a smaller area occurs on the west side of the Accomac anticline. Narrow areas of Harpers phyllite are also present on both flanks of the Mount Pisgah anticline in the southeast corner of the quadrangle. The axes of these folds are shown on Figure 12 (p. 51).

Character and thickness.—The Harpers is a grayish-green quartzose phyllite of uniform texture, banded in places by fine dark argillaceous laminae, and some dark slate containing biotite. Bedding is seldom seen except where quartzose layers are present, because of the perfect development of slaty cleavage, but in the relatively fresh

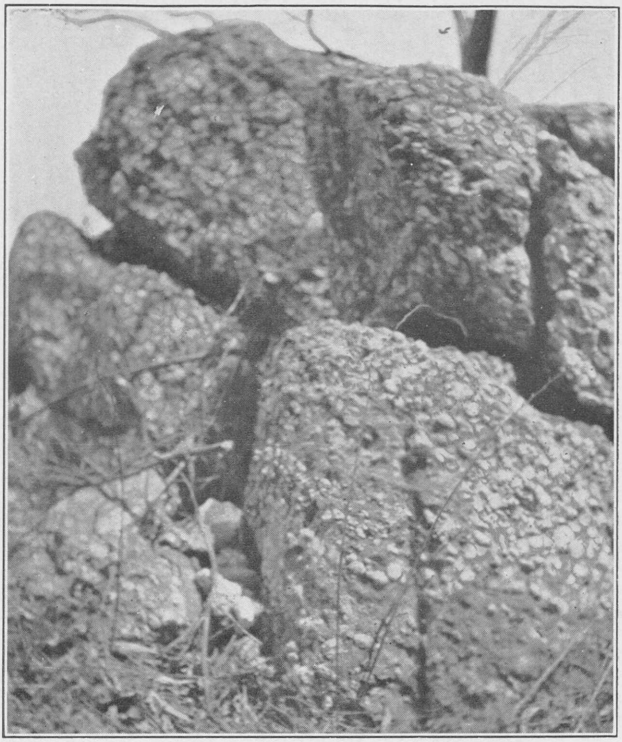


A. VIEW OVERLOOKING THE SUSQUEHANNA RIVER FROM SHOLLS ROCK

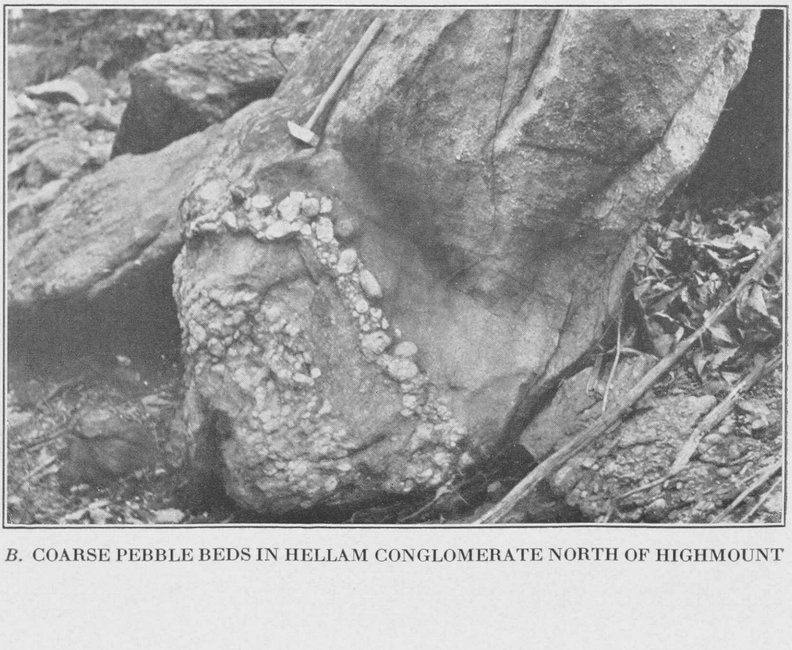
Cliff of gently southward-dipping Chickies quartzite. Bridge of low-grade freight line of the Pennsylvania Railroad in distance.



B. SHARPLY OVERTURNED ANTICLINE OF CHICKIES QUARTZITE IN HARPERS PHYLLITE SOUTH OF CHICKIES ROCK



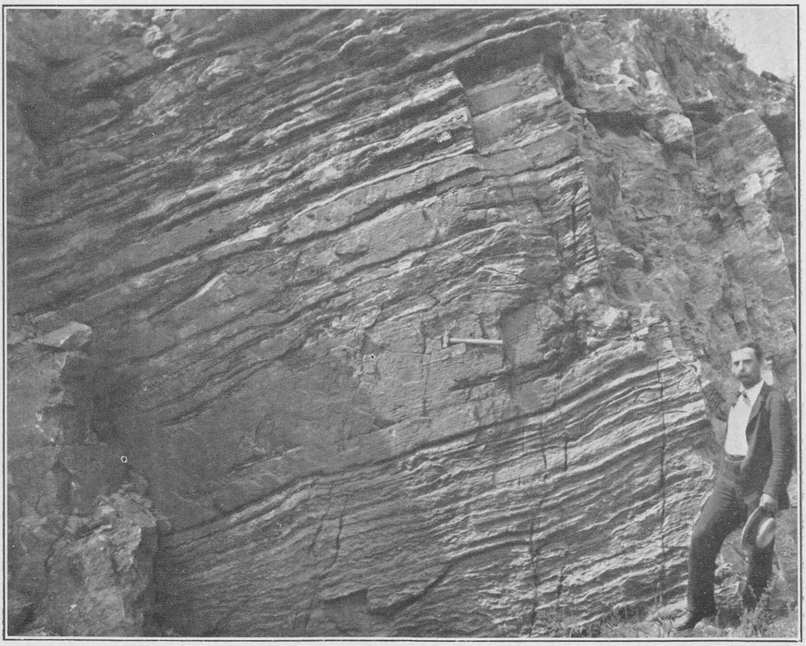
A. THICK BEDS OF CONGLOMERATE IN HELLAM MEMBER OF CHICKIES QUARTZITE NEAR HIGHMOUNT



B. COARSE PEBBLE BEDS IN HELLAM CONGLOMERATE NORTH OF HIGHMOUNT

A. CREEP IN WEATHERED OUTCROP OF HARPERS PHYLLITE 1 MILE NORTH OF COLUMBIA

The cleavage in the bedrock in the road cut dips steeply to the right (southeast) but at the surface is overturned to dip northwest by surface creep on the hill slope. Photograph by C. D. Walcott.



B. BANDING ON WEATHERED SURFACE OF VINTAGE DOLOMITE IN LIMESTONE QUARRY SOUTHWEST OF EMIGSVILLE

Shows varying composition of beds. Photograph by C. D. Walcott.

outcrop on Codorus Creek southeast of Starview the bedding on the nearly horizontal beds is well displayed, cut diagonally by the cleavage, which dips 35° SE. In thin section the rock is seen to be composed of albite, muscovite, and quartz, with some biotite. It is fine grained and has not passed beyond a phyllitic stage of metamorphism. The Harpers phyllite crops out in hackly ledges with steep southeasterly schistosity and breaks into thin cleavage fragments which cover the surface, so that good exposures are few. Owing to surface creep on steep hillsides the cleavage in places is overturned to dip northwest. (See pl. 6, *A*.) Its thickness can not be accurately determined but is estimated at 1,000 feet.

Age and correlation.—No fossils are found in the Harpers phyllite; but as it conformably underlies and grades lithologically into the Antietam quartzite, which has fossils of Lower Cambrian age, it is also Lower Cambrian. It is similar in composition to the Harpers shale of Cumberland Valley, Pa., which there also underlies the Antietam quatzite, but it is more metamorphosed in this area than at its type locality at Harpers Ferry, W. Va., on the Potomac River, from which the formation was named.

ANTIETAM QUARTZITE

Distribution.—The Antietam, the uppermost sandy formation of the Cambrian, crops out along the edge of the quartzite hills of the Hellam Hills anticlinorium. A belt of the Antietam a quarter of a mile wide forms a continuous band on the south side of the Mount Zion and Chickies Rock anticlines from the east side of the Susquehanna River north of Columbia to the southwestward-plunging end of the anticline north of York. It is faulted off west of Pleasureville but appears again as it swings around the head of the limestone valley of the Emigsville syncline to Emigsville, where it passes under the Triassic sediments. A narrow area of the Antietam is brought to the surface at the axis of the Marietta anticline. Another area of the Antietam, possibly brought to the surface on this same fold, lies on the north side of the Harpers phyllite area just south of Saginaw. South of the York Valley at Wrightsville an anticlinal area of Antietam, called the Strickler anticline, lies northeast of Pisgah Hill.

Character and thickness.—The Antietam is a light-gray to rusty-brown quartzite. The lower part is a fine-grained quartz schist somewhat streaked with dark argillaceous matter and grades into the underlying Harpers phyllite. In the middle are harder, blocky coarse-grained quartzites interbedded with the fine-grained layers. A very characteristic blocky iron-bearing fossiliferous granular quartzite that occurs at the top is the means of identification of the formation and furnishes one of the chief keys for unraveling the stratigraphy and structure of the region. It weathers to pitted, iron-stained banded porous angular blocks which, when broken along the bedding, show molds of fossils coated with bright-yellow rust. The residual soil is a deep rich-red sandy clay in which iron ores occur in favorable places.

A clear and complete section of the Antietam quartzite is nowhere exposed in the area. On the west bank of the Susquehanna River north of Wrightsville the exposed part of the quartzite has a thickness of about 65 feet.

The top of the Antietam quartzite is well exposed in the Pennsylvania Railroad cut at Emigsville, where the section is as follows:

Partial section of Antietam quartzite at Emigsville

	Feet
Blocky rust-stained well-bedded granular quartzite, fossilferous (top of formation)	10
Gray thin-bedded quartzite, weathers rusty, with some interbedded shale	60
Sandy gray phyllite and a few thin quartzites (base not exposed	35+
	105+

West of Wrightsville the following section was measured:

Section of Antietam quartzite 1 mile west of Wrightsville

	Feet
Impure sandy dolomite weathering to porous sandstone (Vintage)	50
Antietam quartzite:	
Slabby quartzite with rusty partings and fossil impressions	40
Coarse granular porous-weathering fossiliferous quartzite	10
Quartzite banded with argillaceous streaks, weathering granular and white coated	150±
	200±

The lower limit of the formation is nowhere well defined and has been placed where the quartzose beds begin to be argillaceous; the thickness is therefore variable but averages about 200 feet.

South of Columbia the top of the Antietam is well exposed in the river bluff as follows:

Partial section of Antietam quartzite south of Columbia

	Feet
Knotty gray dolomite, siliceous at base and there contains a small amount of sphalerite (Vintage).	
Antietam quartzite:	
Fine-grained laminated gray quartzite with many beds of ferruginous quartzite composed of glassy quartz grains; contains pyrite and weathers rusty; top layer highly calcareous and full of pyrite and weathers to rusty siliceous skeleton	10
Well-bedded fine-grained gray quartzite with scattered beds of highly ferruginous laminated beds; fossils on bedding planes	30
Bluish schistose quartzite; no bedding observable and thickness not determinable.	

Age and correlation.—The upper part of the Antietam contains fossils wherever exposed in the region, but they are poorly preserved and are difficult to determine. At Emigsville and west of Wrightsville Walcott identified *Camarella minor*, *Olenellus thompsoni*, Hall, *Obolella* cf. *O. crassa*, and *Hyolithes communis*. These forms are of Lower Cambrian age. The same formation occurs in South Mountain, Franklin County, where it is well exposed by Antietam Creek, from which it was named.

VINTAGE DOLOMITE

Distribution.—The Vintage dolomite is the oldest calcareous formation of the Cambrian sequence. It rests conformably on the Antietam quartzite, with which it merges by calcareous sandy beds. The Vintage dolomite occupies a rather large area of lowland near Emigsville, on Codorus Creek and its tributary, in a syncline between the Antietam quartzite ridges north of Emigsville and northwest of Glades. It forms a narrow band along the south side of the Antietam quartzite on the south limb of the Hellam anticlinorium from Wrightsville to the southwestward plunging end of the fold. Another area of Vintage dolomite borders the Antietam quartzite in the Marietta anticline and appears west of the Susquehanna River at Saginaw.

Character and thickness.—The Vintage dolomite is chiefly a dark-blue knotty glistening dolomite. Some beds are coarsely crystalline blue dolomite mottled with white, and some are wavy banded by impurities and have a lumpy appearance on weathering. Other beds are impure blue to white limestone, and certain beds are rather pure mottled gray and white marble. The variability of the beds is shown in the quarry near Emigsville. (See pl. 6, *B*.) There are no continuous exposures of the formation in the region, and its thickness is estimated to be about 1,500 feet. The following composite section was obtained by combining numerous quarry sections and exposures in the fields in the vicinity of Emigsville.

Section of Vintage dolomite south of Emigsville

	Feet
Vintage dolomite:	
Top of formation not exposed.	
Concealed (some beds of white chalky marble weathering to buff tripoli near middle, and some light-gray jointed dolomite in upper part	320±
Pure fine-grained mottled dark-blue and white limestone with some dolomitic bands and lumps (probably *Salterella*-bearing beds)	40±
Coarse crystalline white and black brecciated marble and dark-blue glistening dolomite	180±
Light-blue limestone with coarser dolomite blebs and blue and white streaked and sheared-out limestone with dolomite mud-lump structure; weathers knotty and dirty gray	80
Impure blue and gray mottled sheared-out dolomite; weathers dirty gray	40
Dark-gray sparkling knotty dolomite with coarsely crystalline blebs and stringers and thin bands alternately dark and white; top bed, mud-pellet layer	15
Dark fine-grained dolomite finely banded and showing finely conglomeratic character on weathering	20
Massive light-gray fine-grained dolomite	30
(The 3 units above described are exposed in a quarry in the western part of Emigsville.)	
Light-gray dolomite with coarser dolomite blebs	35
Blue and white laminated marble, with fossiliferous blue limestone at top	90
Concealed (fragments of slabby light-blue limestone with shaly partings)	350±
Spotted dolomite pitted with flat pebble(?) holes on weathering (quarry southeast of Emigsville)	25
Covered	200
Rusty quartzite (Antietam) in Pennsylvania Railroad cut at Emigsville.	
	1,425±

The upper beds are concealed by the Kinzers formation which is overthrust at and west of Myers Mill. The basal beds, not exposed at Emigsville, are seen in the Lancaster Valley to be white to pinkish cream-colored laminated fine-grained marble, which becomes siliceous downward and merges into the Antietam.

Age and correlation.—The Vintage dolomite is in general unfossiliferous, but scattered fragments of trilobites and shells may be found in some of the beds. *Salterella conica* is plentiful in certain pure limestone beds in the upper part of the formation. The fossils are of Lower Cambrian age. The formation was named [11] from its

[11] Stose, G. W., and Jonas, A. I., The lower Paleozoic section of southeastern Pennsylvania: Washington Acad. Sci. Jour., vol. 12, p. 362, 1922.

exposure on the Pennsylvania Railroad at Vintage station, east of Lancaster.

KINZERS FORMATION

Distribution.—The Kinzers formation, which normally overlies the Vintage dolomite, is conspicuous in the area because of its ridge-making shale. The shale forms a prominent ridge south of Emigsville, which extends from the southwest corner of the quadrangle to Codorus Creek, where it is terminated by a fault, and other marked hills in North York and farther north, just south of the Middletown quadrangle. These hills of hard shale with poor thin soil are especially noticeable in contrast to the surrounding fertile lowlands underlain by limestone. A narrow band of the shale forms less conspicuous hills along the north side of the York Valley north and west of Wrightsville and north of Columbia. Shale or other rock of the type composing the Kinzers formation has not been found between the Vintage and Ledger dolomites in the Marietta anticline and is apparently not present north of the Hellam Hills anticlinorium.

Character and thickness.—The Kinzers formation in this area is a hard light to dark gray shale, overlain by impure wavy-banded limestone. At its base is generally a few feet of earthy dolomite that weathers to a soft buff porous tripoli and is one of the few layers from which good fossils can be obtained. The best exposure of the formation in the area is in the Pennsylvania Railroad cut half a mile south of Emigsville, and in the adjacent quarry. The beds, which dip 15° S., are overturned so that the limestone beds of the upper part of the formation dip beneath the shale. The following section was observed:

Section of Kinzers formation half a mile south of Emigsville

	Feet
Light-blue hard limestone, much sheared	
Knotty blue limestone with magnesian mottling	
Banded light-blue limestone with cystid plates and other fossils	80±
Dark massive dolomite	
Laminated mottled limestone with conglomeratic crystalline beds containing cystid plates and other fossils (above beds exposed in quarry)	
Tough dense sandy dolomite, weathering to soft, porous buff tripoli or sandstone	20±
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 to hard red-marked bluish granular quartzite slabs	10±
	260±

The upper beds are better exposed at the old quarry an eighth of a mile north of Myers Mill.

Section of upper part of Kinzers formation at quarry near Myers Mill

	Feet
White crystalline marble, 10 feet (Ledger?).	
Dark blue crystalline limestone full of black *Salterella* shells and fragments of trilobites	5
Dark blue shaly impure limestone weathering earthy (quarry below road)	20
Same rock (above road)	20
Dark limestone breccia cemented by buff dolomite and weathering to lumpy conglomeratic-looking rock	5
Dark limestone with irregular buff dolomite layers, giving rock a wavy mottled banding	10
Impure shaly gray limestone with some earthy fossiliferous bands (quarry above road)	20±
Thick dense, tough earthy dolomite with black streaks weathering to thick fossiliferous porous tripoli	6
Concealed.	
Shale, on hilltop.	86±

Another section of these upper beds along the same strike in the extreme southwest corner of the quadrangle, and also overturned, is as follows:

Section of upper part of Kinzers formation at old quarry south of school on the Liverpool road

	Feet
Black crystalline limestone full of black *Salterella* shells and fragments of trilobites	10
Dark shaly limestone, poorly exposed	20±
Blue limestone (quarried), mostly mottled and wavy banded with argillaceous impurities (in part white spotted marble called "leopard rock") and some pure blue limestone	40±
Tough yellow earthy dolomite, with black streaks and thick tripoli beds full of trilobites and other fossils	10+
Concealed.	
Shale, on hill.	80+

The spotted dark and white marble and dark-banded argillaceous limestone that form a conspicuous upper part of the formation in the Lancaster region are generally not well exposed in the Middletown quadrangle, but they are represented by the 80 to 86 feet of limestones in the sections above.

Age and correlation.—The Kinzers formation is the most fossiliferous formation in the region. Fine specimens of *Olenellus* and other trilobites, cystids, and shells, collected chiefly in the vicinity of Lancaster and York by Noah Goetz, Atreus Wanner, and H. J.

Roddy and described by Walcott,[12] have made this formation noted, and in consequence the shale is called by many the "*Olenellus* shale." The best specimens are obtained from a hackly splitting calcareous shale quarried at several places north of Lancaster for foundation and other stone. The shale is more slaty in the Middletown quadrangle, and no fossils have been found in it, so far as known. Fossils collected by the writers and by C. E. Resser from the earthy beds at the base of the Kinzers at Donnerville in the Lancaster area, have been identified by C. E. Resser as follows:

Bonnia zone:
- Bonnia senecta? (Billings).
- Olenellus fragments.

Fossils collected from the shale in the Lancaster area by the writers and others have been identified by C. E. Resser as follows:

Olenellus thompsoni zone:
- Anomalocaris pennsylvanica Resser.
- Camptostroma radiata Ruedemann (in press).
- Holmia? macer Walcott.
- Olenellus thompsoni (Hall).
- "Olenopsis" roddyi Walcott.
- Paedumias transitans Walcott.
- Roddyia typa Resser.
- Salterella pulchella Billings.
- Tuzoia? dunbari Resser.
- Tuzoia getzi Resser.
- Wanneria walcottana (Wanner).
- Margaretia sp.
- Bonnia sp.
- Acrocephalites sp.
- Pelagiella sp.
- Hyolithes sp.
- Several genera and species of cystids.

Mr. Resser states that this faunal zone occurs also at the Parker quarry, Georgia, Vt.

Fossils have been collected by the writers from the earthy limestones in the upper part of the formation near Myers Mill, south of Emigsville, and other places north of York, and at Rohrersville in the Lancaster area. These have been identified by C. E. Resser as follows:

Nisusia zone:
- Nisusia festinata (Billings).
- Kutorgina cingulata (Billings).
- Paterina bella (Billings).
- Dorypyge marcoui (Whitfield).
- Goniodiscus parkeri (Walcott).

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[12] Walcott, C. D., Cambrian geology and paleontology, III: Smithsonian Misc. Coll., vol. 64, Nos. 3 and 5, 1914 and 1916.

Rustella edsoni Walcott.
Yorkia wanneri Walcott.
Ptychoparia adamsi Billings.
Ptychoparia teucer Billings.
Hyolithes sp.
Olenellus sp.
Bonnia senecta (Billings).
Bonnia bubaris Walcott.
Bonnia capito Walcott.
Cystid plates.

Mr. Resser states that this faunal zone occurs in the section at the Straits of Belle Isle, Newfoundland, and up the St. Lawrence to Quebec, also at Austinville, Va. At these places the underlying shale beds are lacking.

In the report on the Lancaster quadrangle [13] the writers incorrectly listed this fauna from the Vintage, Kinzers, and Ledger formations from collections made by C. D. Walcott and identified by him.

The *Bonnia*, *Olenellus thompsoni*, and *Nisusia* faunal zones are Lower Cambrian.

The formation was named [14] from Kinzers station, on the Pennsylvania Railroad 14 miles east of Lancaster.

LEDGER DOLOMITE

Distribution.—The Ledger dolomite overlies the Kinzers formation in the area south of the Hellam anticlinorium. North of this uplift, where the Kinzers formation has not been recognized, the Ledger rests on Vintage dolomite. In the southwest corner of the quadrangle it occupies only a small triangular area, but this is part of a much larger synclinal area extending southwestward. It also occurs in a narrow belt between the hill of Kinzers formation and the low ridge at the base of the Conestoga limestone on the northwest side of the York Valley. A narrow area of crystalline dolomite south of Hellam is apparently the Ledger brought up in a faulted anticline. The dolomite forms a wider area on the north side of the Marietta anticline, where it lies directly above the Vintage dolomite. At Rowenna it swings northward before crossing the river from Billmeyer to Saginaw, and it is extensively quarried on both sides of the river.

Character and thickness.—The Ledger is usually a very pure uniform coarse-grained dolomite of light-gray color mottled with darker spots, and it weathers to a characteristic deep-red granular

[13] Jonas, A. I., and Stose, G. W., Geology and mineral resources of the Lancaster quadrangle, Pa.: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas, No. 168, pp. 26, 29, 32, 1930.

[14] Stose, G. W., and Jonas, A. I., The lower Paleozoic section of southeastern Pennsylvania: Washington Acad. Sci. Jour., vol. 12, pp. 362, 363, 1922.

soil, but in this area it also contains many thick beds of pure limestone. Almost no exposures of it are seen in the southwestern area, but a white granular marble full of quartz grains crops out on the York highway near the southern border of the quadrangle. Northwest of York there are many quarries in the formation, some in dolomite and some in pure mottled limestone marble. Its estimated thickness is 1,000 feet. The formation is characterized as a pure carbonate rock, with very little siliceous or argillaceous impurities. It ranges from a calcium carbonate to a coarsely crystalline calcium-magnesium carbonate or dolomite and is therefore much sought after for lime burning, flux, and magnesium products. The carbonate was apparently deposited as a pure calcium carbonate, which was later largely altered to dolomite by the replacement of some of the calcium by magnesium from solutions containing magnesia. This change may have taken place in part shortly after the sediments were deposited and while they were still covered by the sea, but it is believed that most of the alteration of these beds occurred after the rocks were hardened and subjected to compression and folding, for the replacement followed joints and brecciated zones along which solutions penetrated the rock and extended outward from these channels. Where complete alteration has taken place the rock is a coarse-grained dolomite. This merges into unaltered limestone along an uneven line that crosses the beds irregularly. The pure fine-grained calcium limestone that has not been altered to dolomite has been made more crystalline by the metamorphism, having been changed in places from a blue crystalline limestone to a white marble. At the border of the altered rock there is a zone of mottled blue and white marble or of spotted marble in which rounded residual masses of blue limestone in a white marble simulate a conglomerate. Evidence of such alteration from blue limestone to marble and to dolomite has been clearly observed in the quarry of the Palmer Lime & Cement Co. and other large quarries around York, where the spotted or "conglomeratic" appearance of certain beds is believed to represent a stage of partial recrystallization, blue masses resembling pebbles in coarse white marble.

A composite section of the lower part of the formation northwest of York is as follows:

Composite section of Ledger dolomite northwest of York

	Feet
Massive gray fine-grained dolomite, some of it "conglomeratic" and oolitic	20
White and some blue marble, in part "conglomeratic," in part oolitic, with a matrix apparently composed of siliceous dolomite which weathers to a porous mass in relief	15
White and blue marble, oolitic in part	30

	Feet
Massive pure-white marble with few wavy dolomitic bands; weathers granular	30
Granular white marble, some very thick massive bedded and "conglomeratic"; weathers to thick dark porous coating	30
White marble, banded with blue; weathers to wavy dolomitic bands in relief	15
Marble, poorly exposed	10
White marble, in part banded and mottled with blue	20
Concealed	175
Shale (Kinzers formation).	
	345

In the Loucks quarry, near Springdale School, 2 miles northwest of York, 15 feet of white saccharoidal limestone marble is exposed, with few coarser dark blebs and magnesian layers at the top. Core drills to a depth of 240 feet show similar white marble with gray mottling, which is reported to contain by analysis 95 per cent or more of $CaCO_3$. Some of the marble cores were tested for ornamental stone and were found to take a fine polish. Similar pure calcium rock, some of which is Ledger dolomite, was formerly extensively quarried in the river bluffs north of Wrightsville (fig. 6, p. 34), where the following section in the north quarry was measured:

Section north of Wrightsville

	Feet
Dark argillaceous limestone (Conestoga).	
Ledger dolomite.	
Thick white granular "conglomeratic" marble and some coarse dolomite	40
Granular light-gray dolomite (horse)	6
Dark bluish-white to pink mottled marble, in part "conglomeratic," and fine-grained gray to pink dolomite; lower part thin bedded; upper part very massive	50
Dark dolomite	10
Blue limestone and dolomite (not quarried)	150±
Hard blue-black shale (Kinzers).	
	256±

North of the Chickies overthrust fault, in the Marietta anticline, the Ledger dolomite is in part a massive gray to blue granular dolomite, and in smaller part fine dark-blue limestone and mottled blue-gray limestone, with a zone of sandy beds near the middle of the formation. This calcareous sandstone is well exposed a mile south of Maytown, where it occurs as beds of hard blue banded sandstone that weathers to yellow slabs scattered through 150 feet of fine dense blue dolomite with a chamois-skin weathering. This medial sandy member is conspicuous in the Lancaster and New Holland quadrangles, east of the Susquehanna River, where it leaves large sandstone blocks and irregular residual masses of porous sandy chert on the surface. The thickness in the Marietta anticline, estimated from width of outcrop and dip of the rocks, is 1,200 feet. In the dolomite quarry of the Baker Co., west of Billmeyer, the rock is largely a massive, coarsely granular light-gray dolomite, but some is dark and well bedded. The upper beds in the quarry are folded and have dark argillaceous partings. In the Baker quarry at Saginaw, south of the river, the rock is largely a rather pure mottled blue well-bedded limestone, overlain by about 40 feet of dark-blue to gray dolomite, showing mud-lump structure and thin knotty argillaceous partings, and at the top 80 feet of dark dolomite with rhythmic white banding, not now quarried.

Age and correlation.—No determinable fossils were found by the writers in this formation in the Middletown quadrangle, but some indistinct spongelike markings were obtained near York and Lancaster. A black calcareous shale collected 1½ miles north of Stoner Station yielded fossils identified by C. E. Resser as *Acrothele decipiens.* This shale is probably above the Kinzers formation and in the Ledger dolomite on the south limb of the Hellam Hills anticlinorium. Fossils have been collected by Atreus Wanner, Charles Schuchert, and C. D. Walcott in a dark sandy shale bed weathering buff earthy, apparently in the Ledger formation, at three localities in York—in Grant Alley near the gas house, at the old Cutcamp's quarry north of Cottage Hill, and at Penn and North Streets. Only one of these localities, that in Grant Alley, can be studied at present because of city development, and from this locality the writers have recently collected trilobites and other fossils. The fossils from this horizon have been identified by C. E. Resser as follows:

Acrothele decipiens Walcott.
Acrothele yorkensis Walcott.
Poliella bala (Walcott).
Agnostus sp.
Chancia n. sp.
Chancelloria yorkensis Walcott.
Zacanthoides sp.
Cystid plates.

Walcott referred this fauna to the lower part of the Middle Cambrian, because of the characteristic forms of trilobites—*Agnostus* and *Bathyuriscus*—and C. E. Resser has recently made the same determination.

The Ledger formation is undoubtedly equivalent to the upper part of the Tomstown dolomite of the Cumberland Valley, which contains fossils of Lower Cambrian age. It is possible, however, that the fossils collected in York are from higher beds in the formation that are of Middle Cambrian age. They are not of the type of beds of the Elbrook limestone, which is Middle Cambrian. The formation was named from Ledger, a village 15 miles east of Lancaster, and is there overlain by the Elbrook limestone of Middle Cambrian age.

CONOCOCHEAGUE LIMESTONE

Distribution.—The Elbrook limestone, a fine-grained light-colored earthy marble which normally overlies the Ledger dolomite in Lancaster Valley and Cumberland Valley, has not been recognized in the Middletown quadrangle, although it may be represented in the lower part of what is here mapped as Conococheague. The Elbrook is exposed near Salunga, in the Lancaster quadrangle, but west of that place the rocks directly above the Ledger contain dark dolomite interbedded with light marble, an association which is characteristic of the Conococheague and not of the Elbrook, and these beds are therefore mapped as Conococheague. There is, however, no evidence of a hiatus in deposition.

The Conococheague occupies a belt 2 to 3 miles wide on the north side of the Marietta anticline and extends westward from the eastern edge of the quadrangle as far as the overlapping Triassic rocks.

Character and thickness.—The formation is not well exposed in the Middletown quadrangle, and a good idea of its general character must be sought elsewhere. It is excellently exposed in the Pennsylvania Railroad cut at Salunga [15] and in the old road-metal quarry at Chickies Creek 4 miles east of the quadrangle, where it is seen to be heterogeneous in character. It is composed of thick beds of pure light-gray limestone, some of which are great *Cryptozoon* reefs, white fine-grained earthy marble, thin-bedded limestone with finely wavy laminæ, dark-blue impure dolomite, sandy limestone beds that weather porous and pitted or to blocky sandstone, and some chert. These different beds alternate and recur many times, and no continuous sequence has been observed. The thickness can only be approximated and has been estimated at 1,500 feet. In the Middletown quadrangle the most conspicuous beds are the white marble, which recurs four or five times across the strike, but the repetition is believed to be due in part to close folding. Some thin sandy beds southeast of Bainbridge are ripple marked. Hard sandy beds, which weather to blocky standstone, and associated hard impure banded limestone of Conococheague type mark the base of the formation and make a line of low stony ridges that passes half a mile south of Maytown. Other less regular ridges of sandstone occur in the formation, one such band passing eastward through Lobata. The upper boundary of the formation is determined by the highest impure beds of this character.

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[15] Jonas, A. I., and Stose, G. W., Geology and mineral resources of the Lancaster quadrangle, Pa.: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas, No. 168, p. 35, 1930.

Age and correlation.—No fossils have been found in the Conococheague limestone in this quadrangle, but it is probable that some of the pure marble beds are *Cryptozoon* reefs, for such reefs in similar beds have been observed at several places in the area to the east. In the Cumberland Valley the formation also contains trilobites and other fossils of Upper Cambrian age, which are referred by E. O. Ulrich to the lower part of his Ozarkian system. It was named from Conococheague Creek, in the vicinity of Chambersburg, where fossils are fairly numerous.

It is probable that the Elbrook limestone, which is not recognized in this quadrangle but which directly underlies the Conococheague limestone a few miles to the east, is absent here, for the Waynesboro formation, composed of red shale and sandstone, is also missing, and there is probably, therefore, a sedimentary break below the Upper Cambrian Conococheague limestone, which represents the Ozarkian system of Ulrich. The beds in the city of York that contain the fauna assigned to the Middle Cambrian by Resser are not of Elbrook type and probably are not part of that formation but belong in the Ledger.

ORDOVICIAN SYSTEM

BEEKMANTOWN LIMESTONE

Distribution.—The Beekmantown limestone is a purer blue limestone that overlies the impure Conococheague limestone and occupies a belt about 3 miles wide which extends westward from Mount Joy to Rheems. It is overlapped diagonally southwestward by red Triassic sandstone. It lies directly south of the Cocalico shale hills, an outlier of which, about 1½ miles long, occurs at Florin. A narrow irregular area of Beekmantown forms an inlier in the Cocalico shale near its southern border. An area of pure blue limestone about 4 miles square at the northwest corner of the quadrangle represents the Beekmantown limestone of the Lebanon Valley exposed north of the Triassic basin.

Character and thickness.—The Beekmantown limestone is largely a well-bedded light-blue rather pure fine-grained limestone with beds of light-gray laminated magnesian limestone, darker-gray dolomite, and white granular marble. The blue beds weather whitish and chalky. A small amount of black chert occurs in a few places. Excellent exposures of the white granular marble may be seen in the cliffs of Little Chickies Creek east of Mount Joy and in quarries in the southeastern part of the town. Many exposures of white marble may also be seen on the road south of Rheems. The variable character of the beds in the Hipple quarry, west of Rheems, and in other quarries near Rheems, especially beds of lenticular dark dolomite veined with white calcite suggests the Conococheague. (See pl. 7, *A*.) The section of these beds in the Hipple quarry is as follows:

Partial section of Beekmantown limestone in Hipple quarry

	Feet
Dark argillaceous limestone.	
Light-gray magnesian limestone	½
Dark-gray argillaceous limestone	3
Magnesian limestone, weathering buff	7
Dark argillaceous shaly limestone	6
Massive magnesian limestone, weathering buff	5
Magnesian limestone	2
Pure light-gray fine-grained limestone with lenticular buff-weathering magnesian limestone or dolomite in the midst which is cut by numerous coarse calcite veins; the nodes are 3 feet apart, and the inclosed lenticular masses are 18 inches thick in the middle	3
Magnesian limestone weathering buff.	

The purest limestone beds generally occur a short distance below the top, and small test pits just west of the shale area at Florin expose about 10 feet of white, light-blue, and black, pure fine even-grained limestone. It contains a little chert and some fine magnesian mottling and weathers to a white chalky surface. This bed is directly overlain by the Cocalico shale.

In the inlier of Beekmantown 2 miles north of Florin the upper beds of the formation are exposed in a small quarry as shown in the following section:

Section at top of Beekmantown limestone 2 miles north of Florin

	Feet
Cocalico shale:	
Black shale.	
Carbonaceous black limestone with fossil fragments	3
Blue-weathering carbonaceous dark limestone containing fossils	5
Beekmantown limestone (upper beds):	
Blocky gray magnesian limestone	5
Dark argillaceous limestone, in part crystalline	½
Gray fine-grained magnesian limestone	10

The total thickness of the formation can not be accurately determined but is estimated to be about 2,000 feet.

Age and correlation.—Fossil shells occur in the Beekmantown but are so tightly embedded that they can seldom be worked out. Cross sections of the white calcite-filled coiled molds of gastropods show on the weathered surface in places. Coiled gastropods, referred by Ulrich to the genus *Ophileta* or *Orospira*, of "upper Canadian" age, were collected by the writers 2 miles north of Mount Joy. All fossils collected from the formation in the region are of Lower

Ordovician age and are assigned by Ulrich to his " Canadian system." The formation is considered to be the same as the Beekmantown limestone at Beekmantown, N. Y.

COCALICO SHALE

Distribution.—The Beekmantown limestone is overlain by shale, which makes hills about 100 feet higher than the limestone lowland. The main shale area is the western part of a larger area that crosses the Lancaster quadrangle and is terminated 3 miles west of the eastern edge of the Middletown quadrangle by the overlapping Triassic sandstone. A small outlying hill of this shale lies north of Florin, a mile south of the main shale area.

Character and thickness.—The Cocalico shale is chiefly a gray or in places black argillaceous shale. The beds near the base are red, purple, and green shale, with thin layers of hard platy sandstone. These lower beds are not clearly exposed for study in the Middletown quadrangle, but their unusual character and wide distribution to the northeast, where they have associated lava, suggest that they may be in part volcanic ash.[16]

Higher in the formation there are beds of soft green feldspathic sandstone and harder green sandstone with glassy quartz grains. Only a small part of the total thickness of the formation, probably not over 400 feet, is present in this quadrangle. The total thickness in the adjacent area is estimated to be over 1,000 feet.

Age and correlation.—Few fossils have been found in the formation in this region. When a few graptolites of uncertain species were collected east of this area, it was thought at first that they were of Normanskill affinity and not Utica or Trenton, so that a new name, Cocalico,[17] was given to the formation, from Cocalico Creek, Lancaster County. This name is also used in the report on the Lancaster quadrangle, just east of the Middletown,[18] recently published by the Pennsylvania Topographic and Geologic Survey. A few poorly preserved fossils, including a small upright gastropodlike *Holopea* were recently found in a thin limestone at the base of or just beneath the formation 2 miles north of Florin and similar fossils 2 miles northeast of Highspire, which are probably of Black River or Trenton age. The overlying shale therefore may be of Trenton and

[16] Stose, G. W., and Jonas, A. I., Ordovician shale and lava in southeastern Pennsylvania: Geol. Soc. America Bull., vol. 38, p. 523, 1927.

[17] Stose, G. W., and Jonas, A. I., The lower Paleozoic section of southeastern Pennsylvania: Washington Acad. Sci. Jour., vol. 12, p. 364, 1922.

[18] Jonas, A. I., and Stose, G. W., Geology and mineral resources of the Lancaster quadrangle, Pa.: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas, No. 168, pp. 39–42, 1930.

younger age and practically equivalent to the Martinsburg shale of the Cumberland Valley, named from Martinsburg, W. Va. However, as Ulrich [19] is still of the opinion that the base of the formation is older than the Martinsburg, the name Cocalico will continue to be used for the shale in the belt southeast of the Triassic sediments.

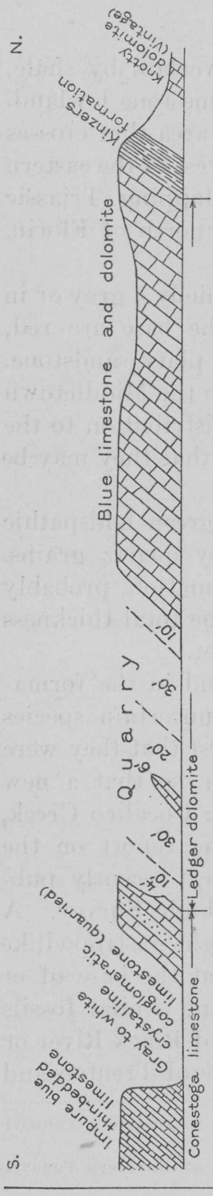

FIGURE 6.—Sketch section of old Stacey-Wilton quarry north of Wrightsville

CONESTOGA LIMESTONE

Distribution.—The Conestoga limestone is an overlapping formation which occurs in the southern part of the York-Columbia-Lancaster limestone valley. It occupies most of this valley between York and Columbia and is about 1½ miles wide where it crosses the southeast corner of the Middletown quadrangle.

Character and thickness.—The Conestoga limestone is chiefly a thin-bedded impure blue limestone with many dark argillaceous partings and is generally in small, tight folds. The lower part of the formation is very heterogeneous in lithologic character. It has many thick beds of limestone conglomerate, a thin bed of black shale which in places is graphitic, and a gray sandstone banded with thin dark argillaceous streaks which weathers earthy. The shale and sandstone beds in this quadrangle are conspicuous enough to be mapped, making a low, nearly continuous ridge close to the Kinzers shale on the north side of the valley. An anticline brings up the sandstone and shale again along a line passing through Hellam and extending nearly to Wrightsville, and a smaller anticlinal area occurs to the south. A small area of granular dolomite at Hellam is apparently the Ledger dolomite exposed beneath the shale and faulted down on the south side. The composition of the lower part of the formation is well shown in the abandoned Stacey-Wilton quarry, north of Wrightsville (see fig. 6), as given in the following section:

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

Composite section of Conestoga limestone and Ledger dolomite in old quarries north of Wrightsville

	Feet
Conestoga limestone:	
Blue thin-bedded limestone	10±
Dark-blue ribbed argillaceous limestone and thick gray granular crystalline limestone (bed which elsewhere carries crinoid plates and stem segments and other fossils)	20±
South quarry rock:	
Sheared white and gray conglomeratic marble	200±
Dark argillaceous limestone (horse)	50
Thick conglomeratic limestone marble	40
Dark slaty limestone	20±
Sandy limestone (ridge maker); weathers to banded sandstone pitted by dissolved limestone pebbles and banded impure limestone	10±
Black fissile shale	40
Black argillaceous limestone; weathers to yellow earthy tripoli	20±
Knotty blue dolomite, dark carbonaceous partings	4
Ledger dolomite:	
North quarry rock:	
White marble weathering dark and light spotted or "conglomeratic" at top	10
Massive white marble	30
Horse of light-gray dolomite	6
Very massive white marble, "conglomeratic" at base	20
White marble, thinner bedded at base	30
Blue limestone	10

The upper part of the Conestoga, not exposed here, is a highly argillaceous limestone that contains in places many beds of dark graphitic shale.

The formation is so much folded and contorted that its total thickness can not be determined. It is estimated to be at least 500 feet thick in the Middletown quadrangle and probably over 1,000 feet thick in the Lancaster region.

Age and correlation.—Few fossils have been found in the formation—none in the Middletown quadrangle. In a quarry of the York Lime & Stone Co., 5 miles east of York and just south of the Middletown quadrangle, a few fossils were collected by the writers from beds near the base of the formation, which R. S. Bassler identified as *Strophomena stosei.* This brachiopod has also been found in the Frederick limestone of Maryland, and the two limestones resemble each other closely in general appearance and are probably of the same general age. But as they occur in areas separated by a wide belt of Triassic sediments extending from Littletown, Pa., to Le Gore, Md., and as only the lower part of the Conestoga in which the fossils occur is known to be represented in the Frederick limestone, the name Conestoga was given to the formation, from Conestoga Creek at Lancaster. The fossils in the Frederick and Conestoga limestones are not known elsewhere, and exact correlation with the general time scale therefore can not be made. Bassler states that the fossils suggest Chazy age. The Conestoga occurs only in areas where the Cocalico shale is not present—that is, the Conestoga limestone occurs only south of, and the Cocalico shale north of, an axis of uplift which runs northeast and southwest from Chickies Rock and is represented by the Honeybrook-Welch Mountain upland and Chestnut Hills to the northeast; Chickies Ridge and the Hellam Hills, in the Middletown quadrangle; and the Pigeon Hills to the southwest. The Conestoga limestone was deposited after a period of post-Beekmantown uplift and erosion.[20] The erosion that preceded the deposition of the Martinsburg and Cocalico shales north of the above-mentioned axis of uplift also took place in post-Beekmantown but pre-Trenton time. If, therefore, the fossils from the Conestoga limestone are correctly interpreted as of Chazy age, the Conestoga is not only older than the Cocalico and Martinsburg shales but its deposition followed an erosion period that occurred probably earlier than that which preceded the deposition of the Martinsburg sediments in the northwest. It is possible that the uplift represented by the Hellam Hills acted as a partial barrier between the two basins in which is recorded a different erosional and depositional post-Beekmantown history. On the other hand, if the Conestoga limestone is of later age than Chazy, it may be in part at least the equivalent of the Martinsburg and Cocalico shales. If this is the case, the erosion period in the area south of the supposed barrier extended also through Black River time.[21]

TRIASSIC SYSTEM

NEWARK GROUP

In the northern part of the Middletown quadrangle the Paleozoic rocks are overlain unconformably by Triassic red sandstone and shale. These rocks are part of the belt of Triassic rocks called the Newark group that extends from New Jersey southwestward across Pennsylvania into Maryland and Virginia. This belt of red rocks, which has a maximum width of about 30 miles at the Delaware River, is 10 miles wide in the Middletown quadrangle. The rocks are in general red, but beds of light-gray sandstone and light-yellow to greenish arkosic sandstone are common in the lower part.

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[20] Stose, G. W., and Jonas, A. I., Ordovician overlap in the Piedmont province of Pennsylvania and Maryland: Geol. Soc. America Bull., vol. 34, pp. 521–524, 1923.

[21] Stose, G. W., and Jonas, A. I., Ordovician shale and associated lava in southeastern Pennsylvania: Geol. Soc. America Bull., vol. 38, pp. 525–526, 1927.

The rocks almost everywhere dip northwestward at an average angle of 30°, though varying locally from 10° to 50°. The aggregate thickness of these rocks determined from the dips of the beds and the width of the outcrop is about 16,000 feet. These sediments were

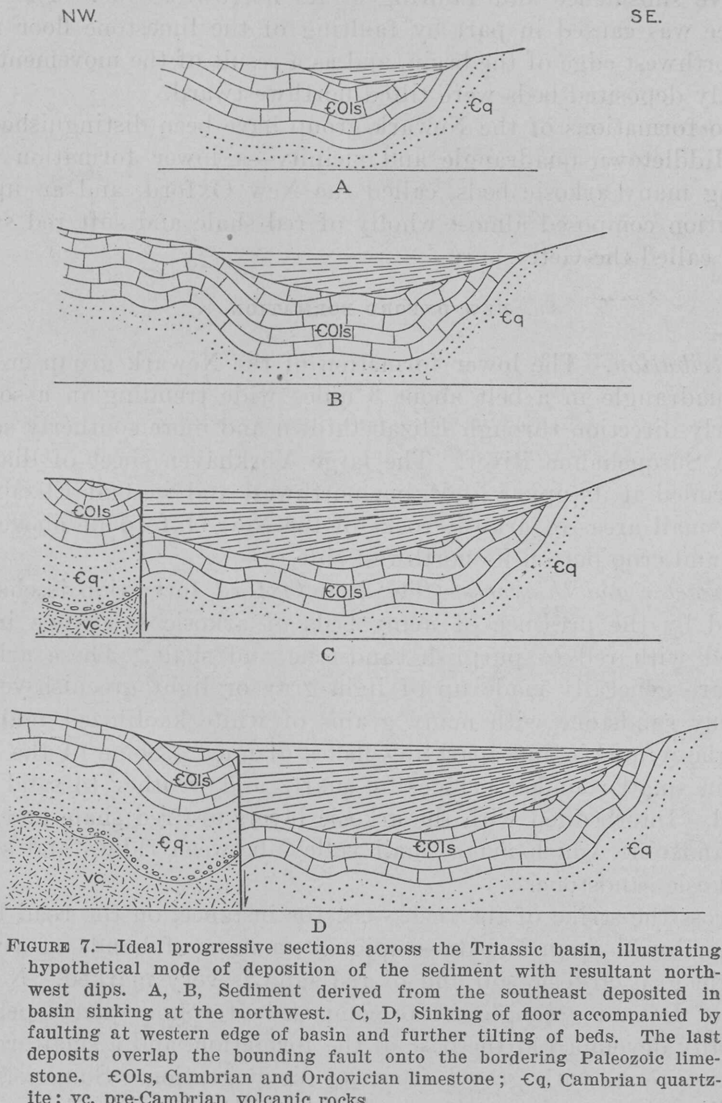

FIGURE 7.—Ideal progressive sections across the Triassic basin, illustrating hypothetical mode of deposition of the sediment with resultant northwest dips. A, B, Sediment derived from the southeast deposited in basin sinking at the northwest. C, D, Sinking of floor accompanied by faulting at western edge of basin and further tilting of beds. The last deposits overlap the bounding fault onto the bordering Paleozoic limestone. €Ols, Cambrian and Ordovician limestone; €q, Cambrian quartzite; vc, pre-Cambrian volcanic rocks

deposited in a long, narrow basin that deepened progressively northwestward, the first deposits being laid down only in the southeastern part of the basin and later deposits spreading progressively farther west. Only a small part of the total thickness of the sediments will therefore be found at any one place. (See fig. 7.)

The sediments were derived almost wholly from an unlifted land mass to the southeast composed of deeply weathered pre-Cambrian crystalline rocks and Cambrian quartzose rocks. The waste from this land was swept into a basin which gradually deepened by progressive subsidence and faulting at its northwest side. The subsidence was caused in part by faulting of the limestone floor near the northwest edge of the basin, and as a result of the movement the recently deposited beds were tilted northwestward.

Two formations of the Newark group have been distinguished in the Middletown quadrangle and vicinity—a lower formation containing many arkosic beds, called the New Oxford, and an upper formation composed almost wholly of red shale and soft red sandstone, called the Gettysburg.

NEW OXFORD FORMATION

Distribution.—The lower formation of the Newark group crosses the quadrangle in a belt about 3 miles wide trending in a southwesterly direction through Elizabethtown and more southerly south of the Susquehanna River. The large Yorkhaven sheet of diabase is intruded at its upper limit, but northwest and west of Elizabethtown small areas of arkosic rocks of the New Oxford lie above the sheet and crop out on its northwest side.

Character and thickness.—The New Oxford formation is characterized by the presence of many beds of arkosic sandstone interbedded with red to purplish sandstone and shale. These arkosic beds are generally made up of light-gray or light greenish-yellow crumbly sandstone with many grains of white kaolinized feldspar and glassy quartz and sparkling flakes of mica. Some of the beds contain small rounded pebbles of quartz and weather to sand and gravel. Interbedded with the arkosic layers are red shale and soft red sandstone, which make small valleys between ridges and spurs of arkosic sandstone.

Across the strike of the rocks—as, for instance, on the road leading northwest from Lobata—rapid alternation of bands of yellow or light-gray arkosic soil and of red sand is very marked. Northwest of Lobata a conglomerate composed of round quartz pebbles is locally developed at the base of the formation, and a small, round hill is covered with gravel from its disintegration. Southwest of the hill and also at Conoy Creek, to the northeast, the basal conglomerate is composed largely of limestone pebbles. The hill east of Mount Wolf is composed of quartzose conglomerate, but beds of limestone conglomerate crop out at the base, near the river. Thin basal beds of purple conglomerate are present also along the west foot of the quartzite hill south of Mount Wolf. The conglomerate beds are shown on the map only where they are of mappable thickness.

The top of the New Oxford formation is placed where beds of light gray arkosic sandstone end. In most places in this quadrangle this is at the base of the Yorkhaven sheet of diabase, but northwest and west of Elizabethtown arkosic beds of the New Oxford lie above the diabase, which here locally crosscuts the upper part of the formation. The thickness of the formation as determined from width of outcrop and dip of beds, if there is no duplication by faulting, is about 6,000 feet.

Unconformity at base.—The New Oxford formation rests unconformably on the Paleozoic rocks that constitute its floor. At the eastern edge of the quadrangle it lies on the Cocalico shale. Westward it transgresses the bedding of that formation and comes to rest on the Beekmantown limestone north of Rheems. The New Oxford formation continues to transgress the bedding of the Beekmantown, overlapping that formation at the Susquehanna River, where it rests on Conococheague limestone. South of the River it rests at Saginaw on the Ledger dolomite, which it overlaps, and near Mount Wolf on the Vintage dolomite. South of Mount Wolf it rests on the Chickies quartzite, and north of Emigsville on the Antietam quartzite.

Age and correlation. Fossils are scarce in the Newark group. Those that have been found are of terrestrial types, in keeping with the terrestrial character of the red sediments. Fragments of fossil wood are reported from three localities—near Elizabethtown, 3 miles northeast of Bainbridge, and 2 miles south and southeast of Yorkhaven. These consist chiefly of residual fragments of silicified wood plowed up in the fields. The only fossil identified from this quadrangle by Wherry [22] and others is *Araucarioxylon vanartsdaleni*, but several other tree species have been collected from these beds in areas to the east. Reptilian bones and teeth were collected in a copper prospect 2 miles northwest of Emigsville, in the New Cumberland quadrangle, and reptilian footprints and fish remains have been found at other places to the east.[22] The fresh-water phyllopod *Estheria ovata* (Lea) was obtained from basal beds of the formation near New Oxford, Pa.[23] From the evidence afforded by these remains the rocks are correlated with the Upper Triassic of Europe.

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[22] Wherry, E. T., Silicified wood from the Triassic of Pennsylvania; Age and correlation of the "New Red" or Newark group in Pennsylvania: Acad. Nat. Sci. Philadelphia Proc., vol. 64, pp. 366–379, 1912.

[23] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), p. 9, 1929.

The New Oxford formation was named from New Oxford, Adams County, where the Triassic formations have been studied in detail and their thickness determined.[23] The formation has the same lithologic character as the Stockton formation, the lower formation of the Newark group in the eastern part of the State, and these two formations are approximately equivalent, but the Lockatong shale, which overlies the Stockton, thins out near Elverson, Pa., and has no representative farther west.

GETTYSBURG SHALE

Distribution.—The Gettysburg shale covers nearly all of the northwest part of the quadrangle north of the Yorkhaven sheet of diabase, and its outcrop is about 7 miles wide. In the extreme northwest corner Paleozoic limestone crops out over an area of about 4 square miles on the northwest side of the Triassic belt.

Character and thickness.—The Gettysburg shale in the type area and also in the Middletown area consists chiefly of soft red shale and soft red sandstone. Northeast of the type area a lenticular mass of heavy conglomerate which makes the Conewago Hills in the New Cumberland quadrangle lies within the formation, and similar lenticular masses of heavy conglomerate and hard sandstone form Elizabeth Furnace Hill, in the Lancaster quadrangle.[24] Beds of conglomerate and hard sandstone occur in the Gettysburg shale in the northern part of the Middletown quadrangle, but they are not so thick or resistant as those to the west and east, above mentioned, nor do they form such high ridges. Thick blocky red sandstones form low ridges to the west and east of Deodate, and a hard pebbly gray sandstone makes a higher ridge 1 mile northwest of Deodate. Other ridges composed of beds of thick pebbly gray and red sandstone occur at the north edge of the quadrangle from Bachmanville to the hills east of Swatara Creek, of which Allen Mountain is the most prominent. The conspicuous ridge-making conglomerates have been mapped. At Waltonville thick sandstone beds, some of which are of very uniform grain for a thickness of 20 feet, have been extensively quarried for dimension stone and building blocks. (See pl. 14.) Very thin irregular layers of coal were found in a conglomerate at the base of the formation at Mount Hope and near Hopeland, in the Lancaster quadrangle, and near Terre Hill, in the New Holland quadrangle,[25] but no coal has been seen in the Middletown quadrangle.

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[23] See footnote 23, p. 39.

[24] Jonas, A. I., and Stose, G. W., Geology and mineral resources of the Lancaster quadrangle, Pa.: Pennsylvania Geol. Survey, 4th ser., Topog. and Geol. Atlas, No. 168, p. 49, 1930.

[25] 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, p. 16, 1926.

The formation is estimated to be 9,000 feet thick. It is known that the beds of the Newark group overlap one another northwestward, and that at no one place is the total thickness present.

Age and correlation.—The Gettysburg shale was named from Gettysburg, Adams County, where it was studied in detail and first described.[26] The general soft shaly character of the formation persists where conglomerate or pebbly sandstone do not predominate. Small fossil shells were collected by the writers in a green shale in the pit of the Royalton Brick Co., Middletown. They have been identified as *Estheria ovata* (Lea), a phyllopod crustacean. The same form has been collected from black shale at the base of the New Oxford formation in the Gettysburg quadrangle and at several places farther east in Pennsylvania. These fossils determine the beds to be of Upper Triassic age. The formation is lithologically similar to the Brunswick shale, the upper formation of the Newark group in the eastern part of the State, and they are approximately equivalent.

TRIASSIC IGNEOUS ROCKS

DIABASE

The Triassic sediments of the Middletown quadrangle have been intruded by diabase in the form of sheets, crosscutting bodies, and dikes. Diabase is more resistant to erosion than the Triassic sedimentary rocks and usually forms prominent hills, of which Roundtop, east of Middletown, is one of the most conspicuous. A thick sheet or sill, called the Yorkhaven sheet, extends from the Susquehanna River northeastward across the quadrangle in the direction of the strike of the sediments that it intrudes. Its northern and upper border passes through Cly, Falmouth, Beverly, Bellaire, Lawn, and Colebrook. Its southern border passes through Yorkhaven and just north of Elizabethtown. West of Yorkhaven it cuts northwestward across the strike of the sediments for 6 miles, beyond the western edge of the quadrangle. The outcrop of the sheet ranges from half a mile to a mile in width. Both the top and the bottom exposed near Lawn dip 30° NW., with the Triassic sediments, and the sheet is 1,600 feet thick.

A crosscutting branch extends north from Newville through Aberdeen and Deodate, where it turns northeast and then more easterly. Although in the part of its course east of Deodate it nearly parallels the Yorkhaven sheet, it is believed to be a steep crosscutting body like that at the Cornwall mine at Cornwall, Pa., 6 miles northeast of the Middletown quadrangle. One reason for this belief is that where the intrusive body is cut by a transverse fault

[26] Stose, G. W., op. cit. (Fairfield-Gettysburg folio), p. 11.

its outcrop is not offset in the manner that an inclined sheet would be but it is greatly narrowed on one side of the fault. At Bachmanville School, where the intrusive body is cut by the north-south fault, it is narrowed from half a mile on the west side of the fault to a knife edge east of the fault, which, in fact, it does not quite reach. Eastward from the fault it expands again in width. Similarly at the diagonal fault at Bachmanville it is reduced from a quarter of a mile in width west of the fault to a knife-edge east of the fault. Farther east it expands again to half a mile in width. This intrusive mass is therefore interpreted as a steep crosscutting body which thins or tapers upward, and in the faulting the two blocks have been tilted southwestward so that at the faults the wedge-shaped mass has been so far depressed that it does not quite reach the surface. In the Lancaster quadrangle this intrusive body unites with the eastern extension of the Yorkhaven sheet through the crosscutting body at Governor Dick Hill.

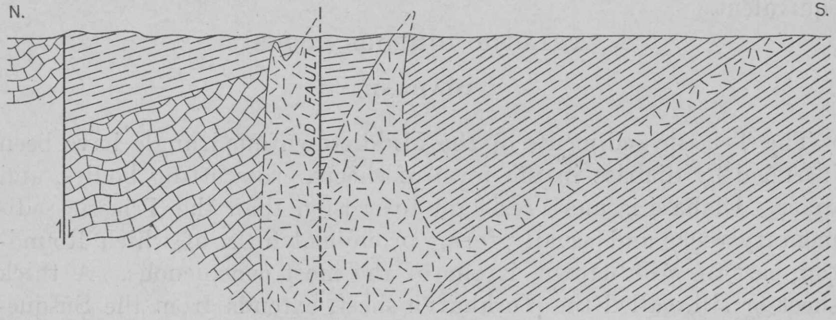
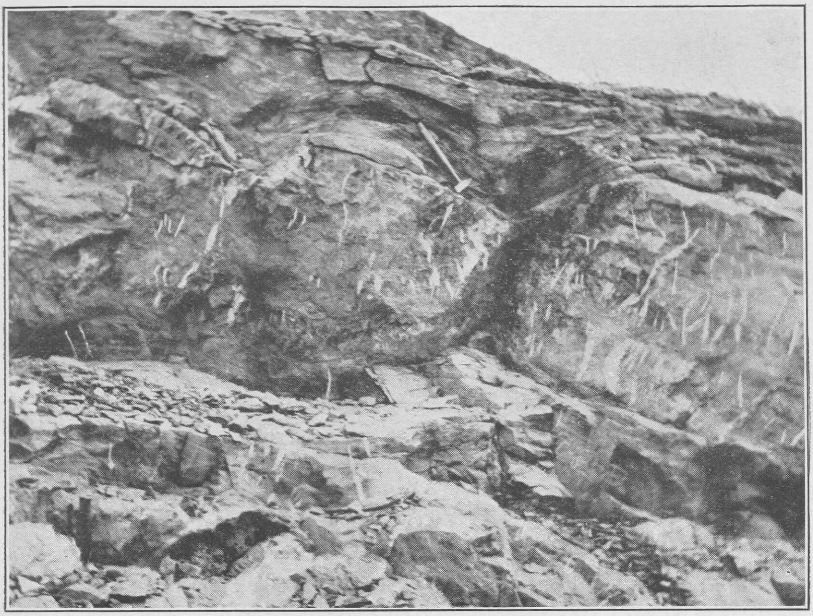


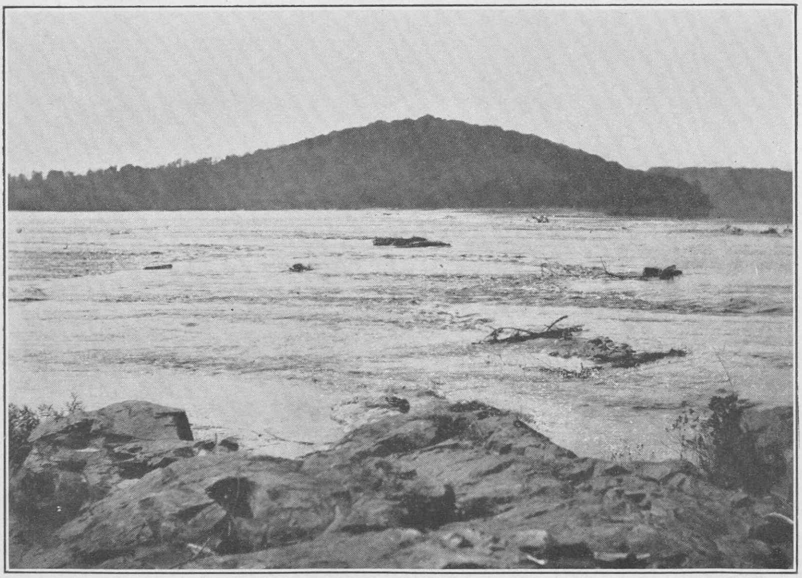
FIGURE 8.—Ideal section of northwestern part of Triassic basin. Shows the Triassic diabase injected along a pre-Triassic fault in the limestone floor at the west edge of the main Triassic basin with a sill of diabase spreading out between the beds. The last sediments deposited lapped over the edge of the basin and are bounded on the northwest by a post-Triassic fault

A second branch of the Yorkhaven sheet extends northwestward from Newville through Swatara Hill. West of Swatara Hill an offshoot of this mass, which appears to be a sill, crosses the river and forms Hill Island (see pl. 7, *B*), beyond which it follows the west bank of the river for several miles in the New Cumberland quadrangle. North of Swatara Hill the intrusive mass expands to 2 miles in width at Roundtop and then splits into two narrow branches that thin out eastward. These are believed to be steep upward-tapering crosscutting masses that plunge eastward, similar to the body at Bachmanville. This intrusive body is believed to have come up along an old fault, probably the one that terminated the deeper part of the Triassic basin. (See fig. 8.) In this respect it is like the diabase mass at Cornwall that came up near the north edge of the Triassic sediments which is at the north boundary of



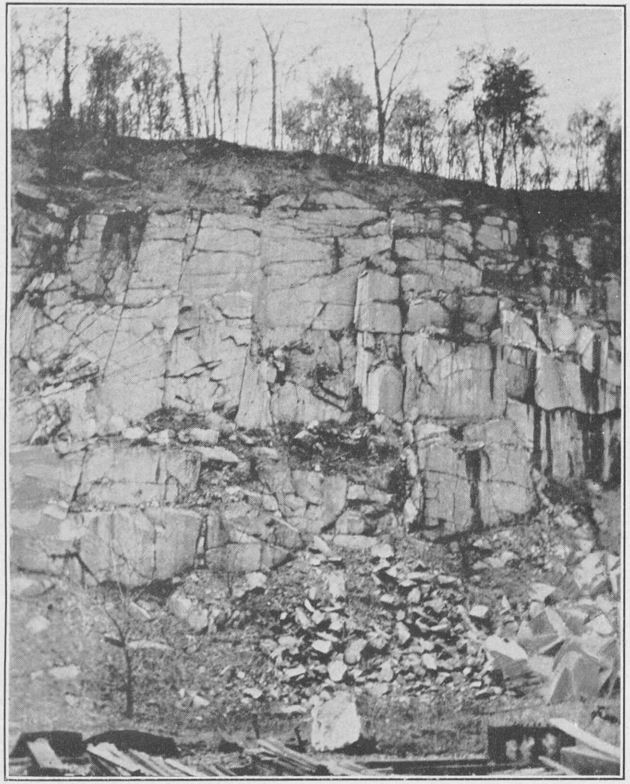
A. LENTICULAR BED OF DOLOMITE IN BEEKMANTOWN LIMESTONE 1 MILE SOUTHWEST OF RHEEMS

Gashed by white calcite veins and interbedded with thin limestone.



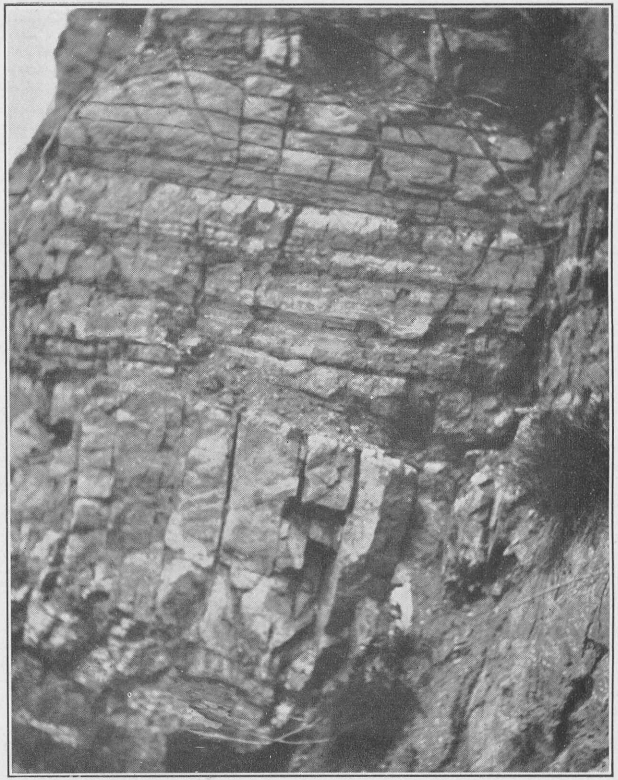
B. HILL ISLAND

Hill of Triassic diabase. Riffles in the river produced by resistant Triassic shale hardened by baking at its contact with its intrusive diabase.

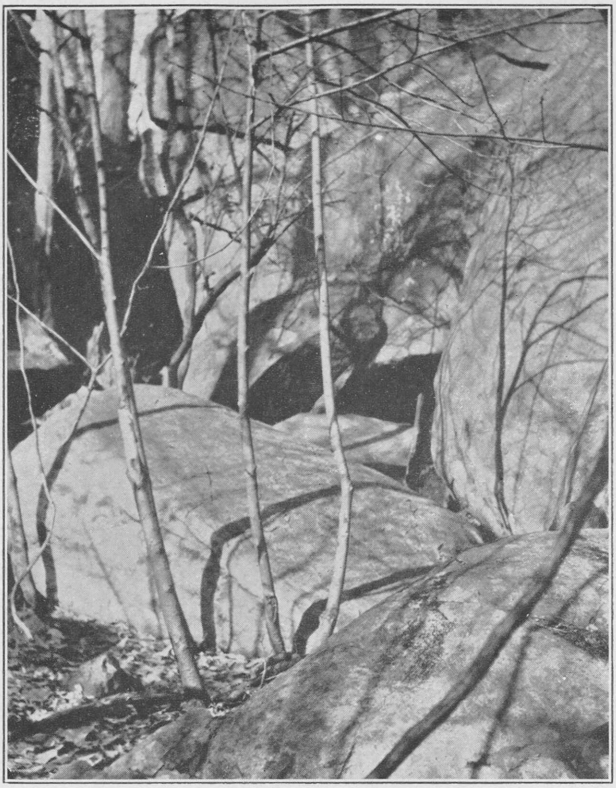


A. LARGE QUARRY IN DIABASE AT YORKHAVEN

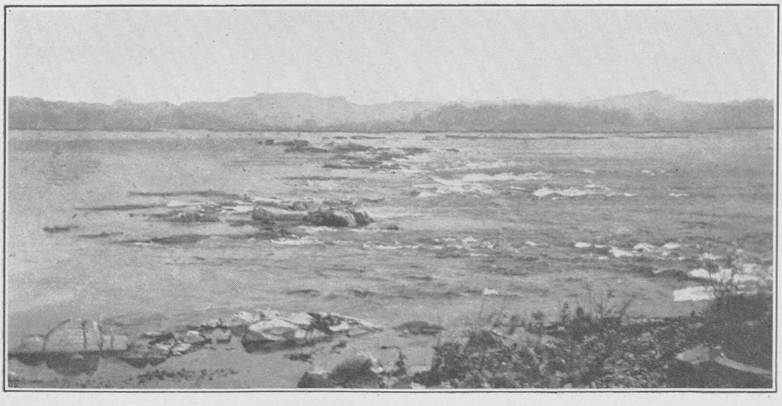
The rock is broken into large blocks by joint fractures. The blocks were used in constructing retaining walls for the Metropolitan Edison power plant.



B. BAKED SHALE WITHIN THE INTRUSIVE DIABASE NEAR BASE OF SILL AT YORKHAVEN

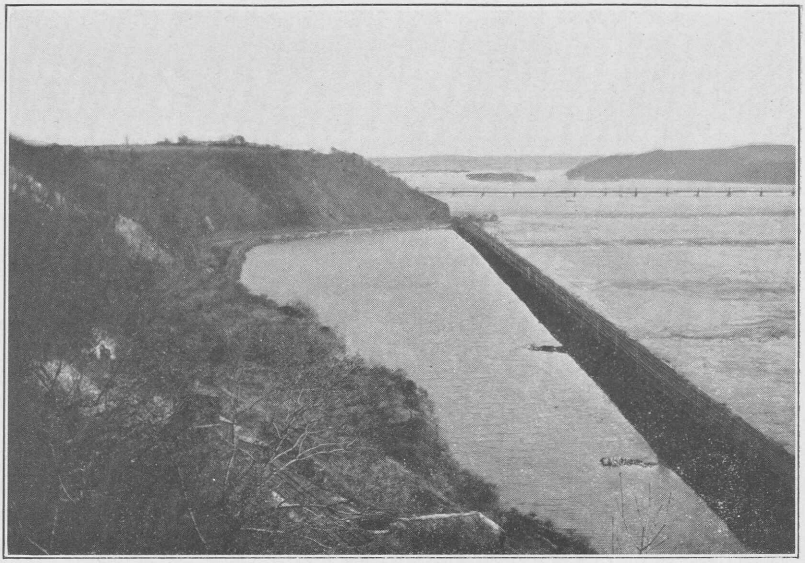


A. LARGE TUMBLED MASSES OF DIABASE THAT FORM THE "GOVERNOR'S STABLE," 1 MILE EAST OF FALMOUTH



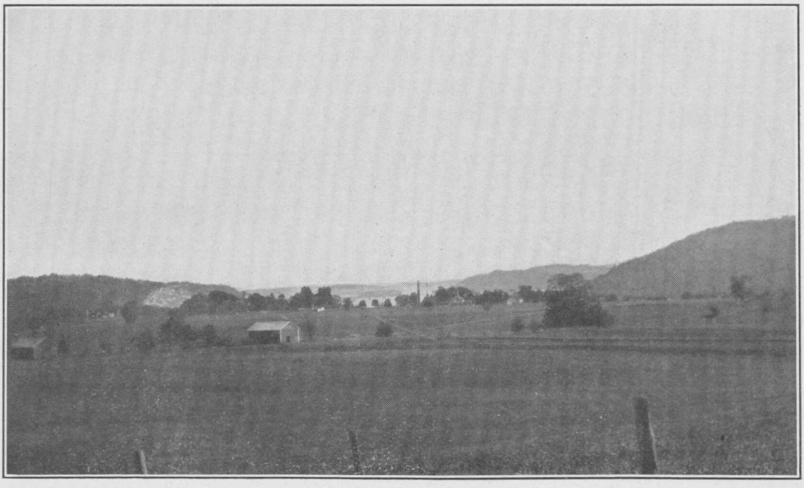
B. HALDEMAN RIFFLES, SUSQUEHANNA RIVER

Made by ledges of diabase dike crossing the river to Billmeyer.



A. LEVEL SURFACE OF 500-FOOT TERRACE NORTH OF COLUMBIA

Covered with scattered river gravel of Bryn Mawr age. View from the 500-foot terrace on Chickies Rock, looking downstream.



B. THE 300-FOOT RIVER TERRACE EAST OF MARIETTA

Probably of Wicomico age. View looking south, down the river, between Hellam Point (at right) and Chickies Rock (white ledges at left).

the deeper part of the basin. The limestone floor may be not much below the surface at the outcrop of this intrusive body (see fig. 8), and the limestone there may possibly be a source of magnetite ore at shallow depth, as it is at the Cornwall mine.

The dikes of the Middletown quadrangle cut across the strike of the Triassic and older rocks. Two are connected at the surface with the Yorkhaven sheet—one 2 miles southwest of Elizabethtown and the other 1 miles west of Yorkhaven. The longest continuous dike in the area is about 14 miles long and extends from a point near the Lancaster-Lebanon County line, in the northeastern part of the quadrangle, southwestward to Billmeyer and across the Susquehanna River east of Starview. The prominent ledges it makes in the river produce the Haldeman Riffles. (See pl. 9, *B*.) It is paralleled in places northeast of Elizabethtown by several shorter

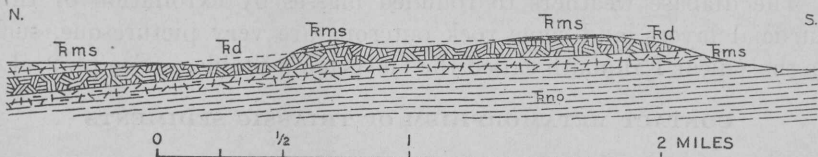


FIGURE 9.—Section showing remnants of roof of Triassic sediment on diabase sill west of Yorkhaven. Trno, New Oxford formation; Trd, diabase sill; Trms, metamorphosed beds at diabase contact

dikes on each side of it. These dikes fill fissures in the sedimentary rocks and crop out in the Paleozoic sedimentary rocks south of the cover of Triassic rocks as well as in the Triassic area. They follow a general northeasterly direction.

The diabase of the Yorkhaven sill and larger crosscutting bodies is medium to coarse grained, with fine-grained border; the dikes are all fine grained. The diabase is a black to gray crystalline rock with a diabasic or ophitic texture. Its chief constituents are grayish feldspar and sparkling green augite. In the coarser-grained variety feldspar predominates and the rock is locally called a "granite" and has been extensively quarried at Yorkhaven for heavy masonry walls. (See pl. 8, *A*.) Other minerals present, which can be detected in thin section, are magnetite, apatite, and a little quartz. The diabase near Elizabethtown is normal augite diabase; the feldspar, an acidic labradorite, occurs in lath-shaped crystals variously oriented. Some orthoclase in micrographic intergrowth is present. Some of the augite is altered to uralite and clustered about with biotite and magnetite. The biotite is altered to chlorite and magnetite, which fill spaces originally occupied by augite.

The diabase varies in grain, being coarser in the central parts of the sheets than near the edges. It is uniform in mineral composi-

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tion, and no evidence of differentiation was found except west of Yorkhaven, in the upper part of the sheet, where a portion of the roof of sedimentary rock is preserved. (See fig. 9.) Here a pink pegmatite containing hornblende was found in boulders in a stone wall. In thin section its chief constituent, feldspar, is dusted with fine hematite and is kaolinized. Some albite twinning and microperthite are still visible. Fibrous hornblende is the ferromagnesian constituent and is probably secondary. In the boulders it cuts the fine-grained diabase; hence it seems probable that it occurs in dikes in the normal diabase and that it owes its presence to concentration of volatile constituents and to differentiation of the sill at this point. Such an explanation has been given for acidic differentiates of diabase at Goose Creek, Va.,[27] and elsewhere at upper contacts of basic sills.

The diabase weathers to rounded masses by exfoliation of thin surficial layers, and some rock outcrops are very picturesque, such as those near Falmouth called the Governor's Stable. (See pl. 9, *A*.)

CONTACT METAMORPHISM OF TRIASSIC SEDIMENTS

The diabase intruded the sedimentary rocks while hot, baked them into hard rock, and in places developed new minerals in them. The shales and sandstones have been hardened to dense porcelanite and their color has been changed from red or brown to blue-black by reduction of the iron oxide. Some of the altered sandstone, however, is light gray to white. The new minerals developed are epidote and chlorite in nodules that weather out on the surface as round knots.

Bands of baked sediment border the top and bottom of the intrusive diabase and are shown on the geologic map. The absence of baked shale between diabase and red sediment is an evidence of normal faulting, which otherwise is hard to trace in the Triassic rocks. Mineralized contact rocks may be clearly seen in the quarry a mile east of Upper Lawn, on the upper side of the Yorkhaven sheet south of Falmouth along the river, 1 mile west of Yorkhaven near Conewago Creek, and half a mile west of Yorkhaven.

The baked shale is generally so hard that in places it is more resistant to weathering than the diabase and makes the crests of the ridges. Where the diabase and shale cross the river to Hill Island, south of Middletown, the baked shale at its upper contact is more resistant than the diabase and produces marked riffles. (See pl. 7, *B*.) The contact of diabase and baked shale north of Lawn

[27] Shannon, E. V., The mineralogy and petrology of intrusive Triassic diabase at Goose Creek, Loudoun County, Va.: U. S. Nat. Mus. Proc., No. 2539 (vol. 66, art. 2), pp. 29–40, 1924.

strikes N. 20° E. and dips 30° NW. The shale at the contact is dense blue-black porcelanite and contains magnetite and knots of green hornblende. The mineralization and hardening decrease rapidly northwest of the contact, and at 160 feet from the contact is found the normal unaltered soft red shale. At most places the altered zone is apparently much wider.

North of Falmouth baked shale crops out prominently at the river and produces rapids where it crosses the river in a southwesterly direction. It dips 35° NW. The rock is a bluish-black hornstone with knots of epidote. In thin section it is seen to be composed of a fine network of hematite and quartz and to contain knots with irregular outline consisting of fine grains of quartz, feldspar, epidote, and hematite. Farther away from the contact the rock is much finer in grain and does not contain epidote.

The shale at the lower contact of the sheet is also baked so hard that it makes riffles in the river, called Conewago Falls. An excellent exposure of these baked sandstones and shales in the form of dark and white banded rock occurs at the south contact of the sheet at Yorkhaven (pl. 8, *B*), where a lower diabase sill may be seen 5 feet below the main sheet, within the metamorphosed shale.

A mile west of Yorkhaven, near Conewago Creek, a diabase dike that extends southwestward from the main Yorkhaven sheet has altered a sandstone bed of the Gettysburg shale. The usual effect of diabase on the sandstone is induration and changing of color from purplish red to light gray or white, with recrystallization until it has the appearance of a sparkling crystalline quartzite. The altered sandstone near the dike west of Yorkhaven, however, has been almost entirely epidotized and during the mineralization hematite was introduced. The altered rock is a green epidotic sandstone in which the form of the original pebbles is preserved. The epidotic sandstone is found only in contact with the dike; the baked sediment next to the base of the Yorkhaven sheet, of which the dike is an offshoot, is blue-black and contains no epidote nor hematite. It seems likely, therefore, that the emanations that produced the epidote and hematite proceeded along the small fissure occupied by the dike.

The pink hornblende-bearing pegmatite half a mile west of Yorkhaven occurs adjacent to a remnant of the sandstone cover of the Yorkhaven sheet. This remnant, not removed by erosion, is a quarter of a mile by half a mile in extent. It is a banded light and dark gray hardened sandstone and contains epidote and abundant garnets. In thin section this rock is seen to be made up of green hornblende grains in a fine cloudy groundmass of quartz and sericite. The garnets have crystal form with ragged outline and contain abundant hornblende inclusions. They exhibit zonal structure, grading from resinous brown in the center to colorless on the edge. Garnets have not been found elsewhere in metamorphosed Triassic sediments of the Middletown area, and their occurrence in the sandstone over that part of the sill in which there has been magmatic differentiation may have been the result of abundant water in the underlying sill and addition of material from the magma at that point.

TERTIARY SYSTEM

HIGH TERRACE GRAVEL

Gravel deposits at three levels.—Remnants of river gravel on several high terraces are preserved in the Middletown quadrangle.[28] The highest gravel deposits are on a bench on the north side of the Hellam Hills, at an altitude of 720 to 740 feet. The bench is narrow and approximately parallel to the river. The gravel is composed largely of rounded pebbles and cobbles of milky-white quartz in a white sand matrix, in places cemented by iron oxide and the pebbles rust stained. The gravel has been observed over a length of only a quarter of a mile where crossed by roads, but white sand, in part cemented by iron rust, extends largely over the surface of the flat bench for more than a mile. Cobbles derived from these terraces are scattered over the slope below.

A lower terrace at an altitude of 620 feet lies half a mile north of the higher gravel on the slope of the Hellam Hills and that much nearer the river. Pebbles of Juniata ("Red Medina") sandstone and fossiliferous quartzite, probably Oriskany, as well as white quartz, occur in this gravel. The bench on which gravel has been found at several places is over a mile long. The gravel is best displayed in cleared fields on the upland, 1 mile east of the mouth of Codorus Creek. Some of the gravel is cemented to a hard ferruginous conglomerate, fragments of which are found on slopes below. Scattered round pebbles and cobbles and sand have also been found on the quartzite hills at this level 2 miles southeast of Wrightsville.

Still lower deposits of gravel occur at several places in the quadrangle at altitudes of about 500 feet. The terrace represented by these deposits is well defined at and south of Chickies Rock (see pl. 10, *A*), and scattered pebbles and cobbles are found on these remnants of a gravel-covered plain. Similar scattered gravel and sand occur at this level on the hills south of Roundtop, west of the river, and small benches at about this level on the south slope of Chestnut Hill, northeast of Columbia, are also capped by gravel. (See fig. 10.)

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[28] Stose, G. W., High gravels of Susquehanna River above Columbia, Pa.: Geol. Soc. American Bull., vol. 39, pp. 1073–1075, 1928.

Origin and age.—These gravel deposits are all close to the Susquehanna River and are undoubtedly remnants of gravel laid down by the river when it flowed at higher levels. At the time each of these deposits was formed, the flood plain of the river stood at that level and all the surrounding country was above that level, though much of it has since been worn away. The highest gravel was deposited first and is the oldest; the river then cut down 100 feet or so, when the second gravel was deposited; again the river cut down 100 feet or so, and the third gravel was deposited. Each gravel bench marks a period of prolonged erosion, the cutting of a broad, flat flood plain, and deposition of gravel on the plain.

The lowest of these high gravel deposits is believed to represent the Bryn Mawr gravel. Small remnants at about this level have been found in the narrow gorge of the river south of this quadrangle and connect with extensive gravel-covered flat uplands at altitudes of 400 to 460 feet at the fall line near the mouth of the river at

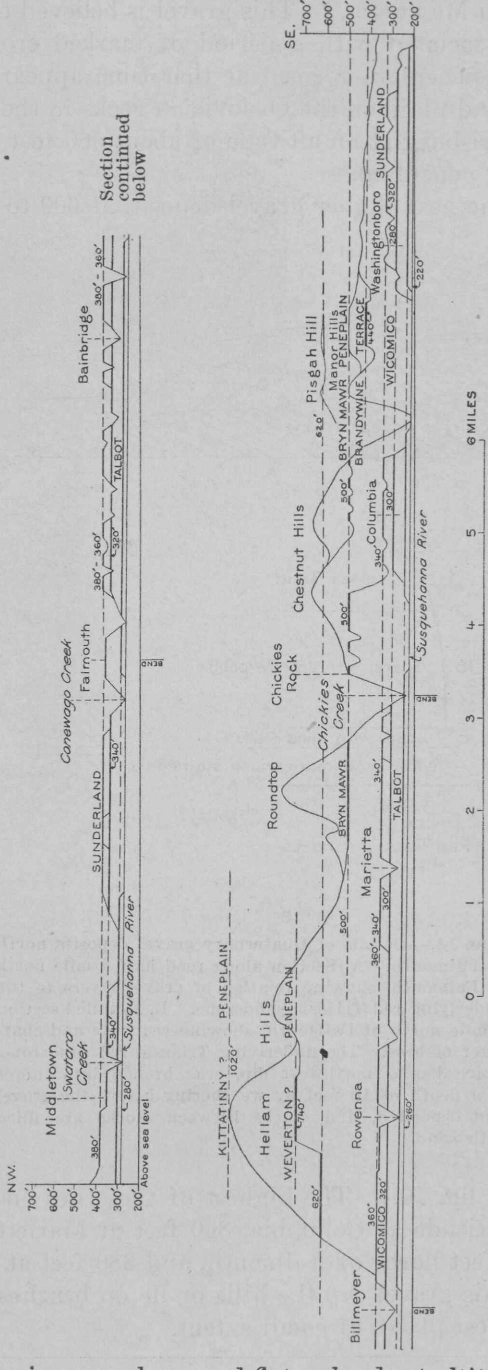

FIGURE 10.—Profile along Susquehanna River in the Middletown quadrangle showing gravel-covered terraces and peneplain surfaces. Gravel on terraces represented by heavy line

Bryn Mawr, Pa.[29] This gravel is believed to be of Pliocene age and is associated with a period of marked erosion and peneplanation. The peneplain formed at that time appears to be the same as the upland plain on the Ordovician rocks in the limestone valley around Harrisburg at an altitude of about 560 feet, there called the Harrisburg peneplain.

The next higher gravel deposit, at 600 to 620 feet, is considerably older and may represent an earlier Tertiary period of peneplanation — Miocene or Eocene. Remnants at this level are also found on the brink of the river gorge south of the quadrangle. The highest gravel, at 720 to 740 feet, which is 500 feet above the present level of the river, is much older and represents deposition of river gravel in either Eocene or possibly late Cretaceous time.

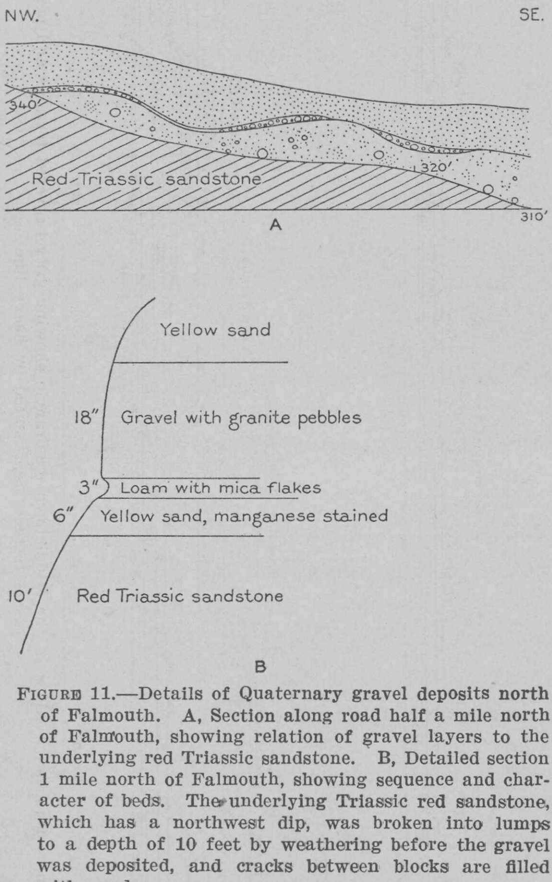

FIGURE 11.—Details of Quaternary gravel deposits north of Falmouth. A, Section along road half a mile north of Falmouth, showing relation of gravel layers to the underlying red Triassic sandstone. B, Detailed section 1 mile north of Falmouth, showing sequence and character of beds. The underlying Triassic red sandstone, which has a northwest dip, was broken into lumps to a depth of 10 feet by weathering before the gravel was deposited, and cracks between blocks are filled with sand

QUATERNARY SYSTEM

LOWER TERRACE GRAVEL

Gravel deposits at three levels.—The deposits of terrace gravel are also preserved at three levels in the quadrangle.[30] (See fig. 10.) The highest of these lies on a bench that is 340 feet in altitude at Columbia, 360 feet at Marietta and Billmeyer, 360 to 380 feet north of Falmouth, and 380 feet at Middletown. Remnants of this gravel cap the hills or lie on benches along the river and are in most places of small extent.

[29] Stose, G. W., Is the Bryn Mawr peneplain a warped surface?: Am. Jour. Sci., 5th ser., vol. 19, pp. 178–179, 1930.

[30] Stose, G. W., High gravels of Susquehanna River above Columbia, Pa.: Geol. Soc. America Bull., vol. 39, pp. 1075–1085, 1928.

The next lower terrace gravel is on a bench that is 300 feet above sea level at Columbia and Marietta, 320 feet at Bainbridge, and 340 feet from Falmouth to Middletown. Details of the gravel layers and of their contact with the floor of red Triassic sandstone are shown just north of Falmouth. (See fig. 11.) Remnants of this terrace gravel are of much larger extent, being in places 1 mile wide and several miles long. (See pl. 10, *B*.)

The lowest terrace is only 20 feet above the river and merges in places with the present flood plain, so that the two are mapped together.

Age and relations.—The three lower deposits of terrace gravel all contain pebbles and cobbles of granite and other igneous rocks, metamorphic rocks, various quartzites, and chert. Some of these are rock types not found in the upper drainage basin of the Susquehanna. Such extraneous material was evidently brought into the basin by glaciers. Boulders 5 to 10 feet in largest dimensions are plentiful on the two lower terraces and were evidently ice borne, indicating a cold climate, and some of the boulders are striated by glaciers or by floating ice. The uppermost terrace was traced by Leverett [31] up the river from Harrisburg and was found to connect with a moraine of the Illinoian glacier. It is therefore probably of Illinoian age. The middle terrace is probably of early Wisconsin age, and the lower terrace of middle or late Wisconsin age. The terraces have also been correlated by the writer [32] with the three terraces in the Coastal Plain at the mouth of the river, as follows: The terrace gravel at 340 to 380 feet is correlated with the Sunderland formation; that at 300 to 340 feet with the Wicomico formation; and the lower terrace gravel with the Talbot formation. (See fig. 10.)

FLOOD-PLAIN ALLUVIUM

Alluvium covers the flood plains of the larger streams. Along the Susquehanna it is wide and could be readily mapped separately on a map with a contour interval less than 20 feet. It is here mapped with the lower terrace gravel. On smaller streams no attempt has been made to map the alluvium. The alluvium exposed on the flood plains is composed largely of sand and silt, but probably there is a foundation of coarse gravel beneath the sand. Fine particles of coal, washed from the culm piles in the coal field in the northern part of the State, are deposited with the sand, and the bars in the bottom of the river below Columbia are extensively dredged and the sand washed to separate the coal.

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[31] Leverett, Frank, Results of glacial investigations in Pennsylvania and New Jersey in 1926 and 1927 [abstract]: Geol. Soc. America Bull., vol. 39, p. 151, 1928.

[32] Stose, G. W., op. cit. (1928), pp. 1077–1079.

GEOLOGIC STRUCTURE

The structure of the Triassic rocks in the northern part of the quadrangle and that of the Paleozoic rocks in the southern part are so different that they will be described separately. The Paleozoic rocks were compressed into close folds that trend northeastward, and many of the folds are overturned toward the northwest and some are broken by faults on which the rocks have been overthrust northwestward. The Triassic rocks, which were deposited after the folding of the Paleozoic rocks took place, are not folded but have been tilted rather uniformly northwestward and broken into blocks that have been displaced by normal faults. These faults have also affected the rocks of the Paleozoic area and materially modified the earlier structure.

AREA OF PALEOZOIC ROCKS

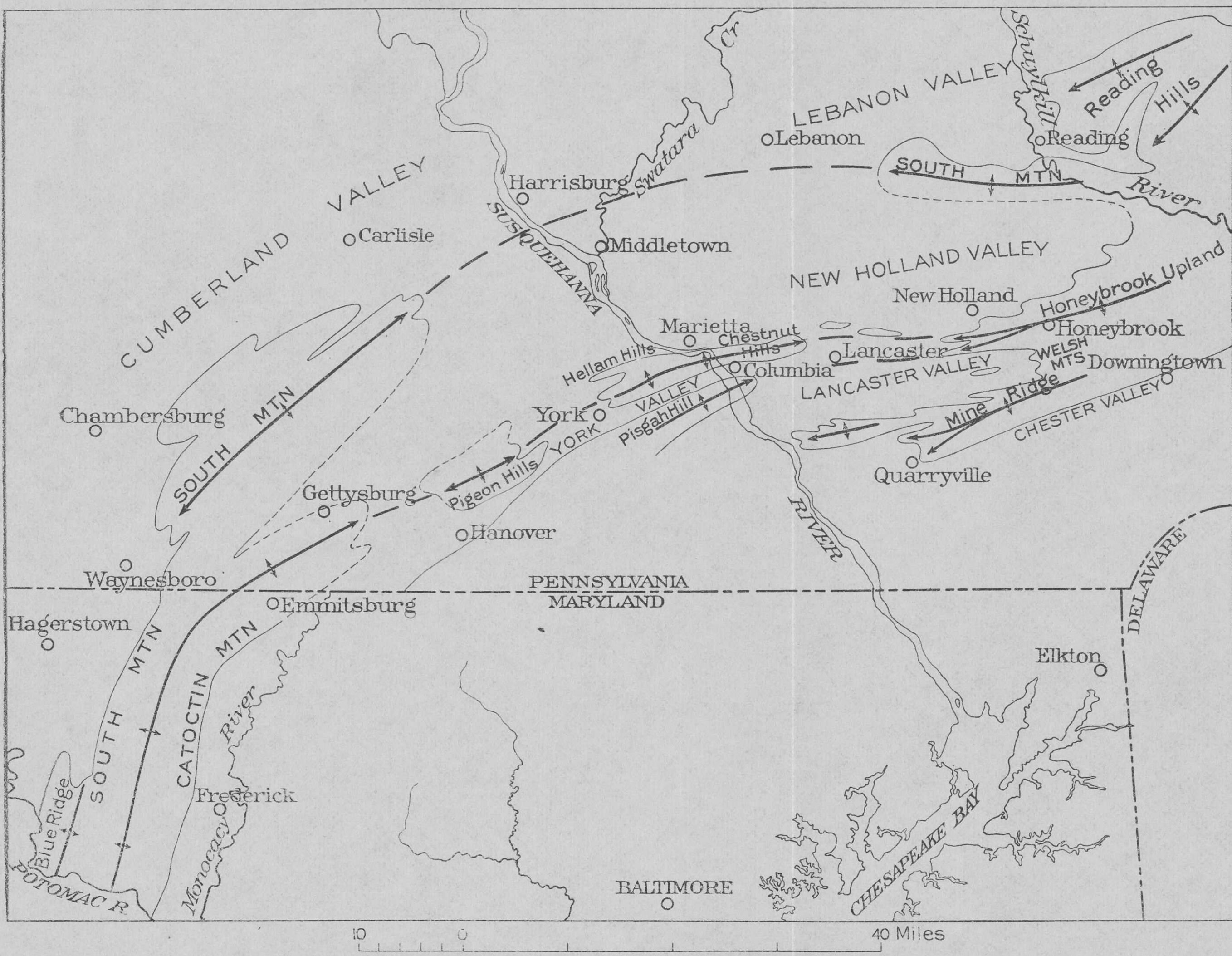
The folds in the Paleozoic rocks in the southern part of the quadrangle, together with the Pigeon Hills uplift in strike to the southwest and the Chestnut Hills uplift and other folds to the northeast, are part of the Blue Ridge-Catoctin Mountain anticlinorium of southern Pennsylvania and Maryland. (See pl. 11.)

The largest fold of the quadrangle is the Hellam Hills anticlinorium which lies just south of the Susquehanna River. The Marietta anticline lies north of this fold and the Wrightsville syncline south of it, between the Hellam anticlinorium and the Mount Pisgah anticline, in the extreme eastern part of the quadrangle. (See fig. 12.)

HELLAM HILLS ANTICLINORIUM

The Hellam Hills anticlinorium is made up of four anticlines—the Mount Zion, Accomac, Chickies Rock, and Trout Run. The Mount Zion, Accomac, and Chickies Rock anticlines are along the same general axis and are apparently parts of the same fold. A branch of the Emigsville syncline lies between the Mount Zion and Trout Run anticlines.

The Mount Zion anticline is an elongated uplift exposing mainly the coarse conglomerate beds of the Hellam member of the Chickies formation, which forms the ridges at Mount Zion and northeastward. Northwest of Hellam the underlying pre-Cambrian volcanic rocks are exposed at the axis of the fold. The anticline plunges to the southwest at Pleasureville, and the quartzite of the Chickies, the Harpers phyllite, the Antietam quartzite, and overlying limestones wrap around the end of the fold of conglomerate. The fold is broken along the north side and is thrust northwestward on the Glades thrust



MAP OF THE MAIN PALEOZOIC STRUCTURAL FEATURES OF SOUTHERN PENNSYLVANIA AND ADJACENT PART OF MARYLAND

Triassic sediments and faults omitted. Pitch of folds indicated by arrows at ends of anticlinal axes. Light lines are boundaries of Lower Cambrian quartzites exposed in anticlines. The South Mountain anticline in southern Pennsylvania is in trend with the South Mountain and Reading Hills uplift in the eastern part of the State; the Catoctin Mountain, Pigeon Hills, Hellam Hills, and Chestnut Hills anticlines are in trend with the anticline of the Honeybrook upland.

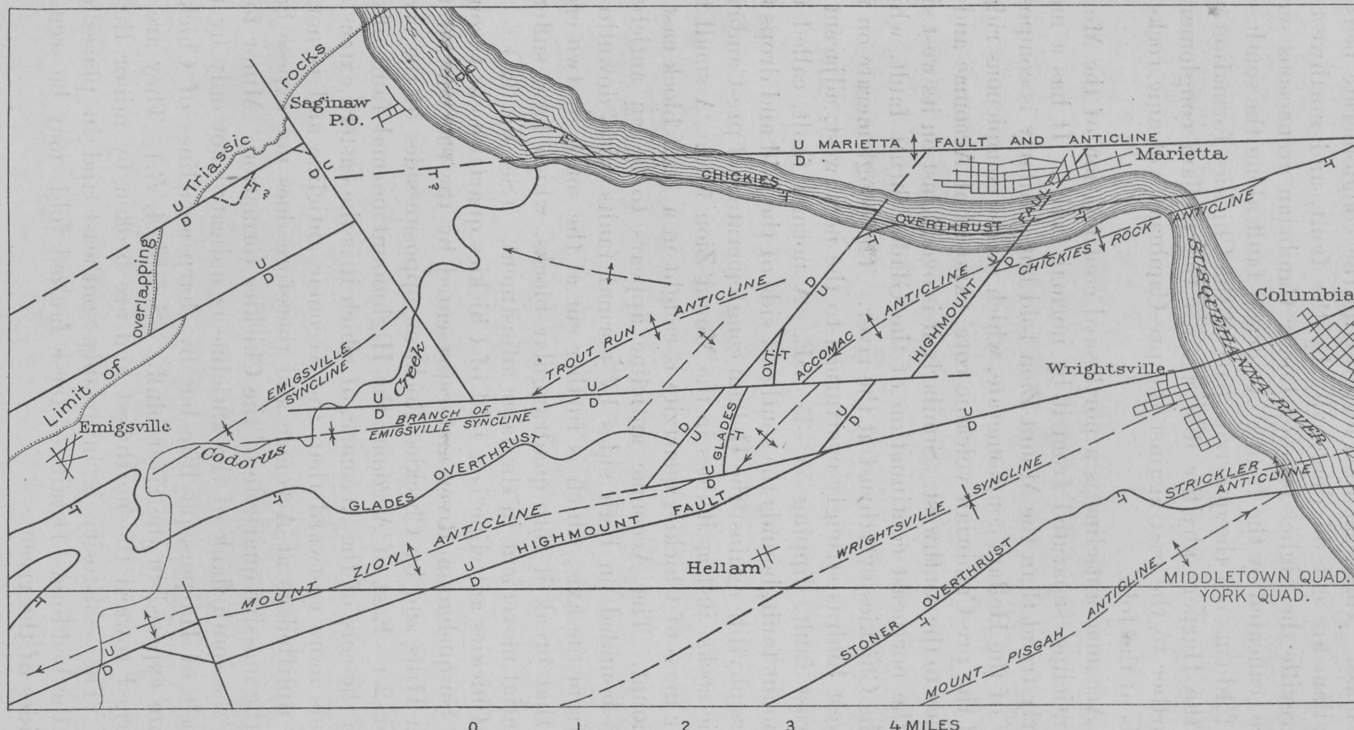


FIGURE 12.—Sketch map showing major faults and structural axes of the Middletown quadrangle. T, Overthrust side of thrust fault; D, downthrown side of normal fault; U, upthrown side

fault. The fault plane cuts diagonally across the beds in the overthrust mass. Northeast of Pleasureville the conglomerate beds in the Hellam are cut off diagonally by the fault, and northwest of Pleasureville the higher beds of Lower Cambrian arenaceous series also are truncated by the fault. A normal fault along the south side of the fold cuts out the quartzite part of the Chickies formation and drops the Harpers phyllite first against the Hellam conglomerate and farther to the east against the pre-Cambrian volcanic rocks in the axis of the fold.

The Accomac anticline is a northward continuation of the Mount Zion anticline, separated from it by normal faults. It has a more northerly trend than the Mount Zion fold but similarly is composed largely of the Hellam conglomerate, which makes conspicuous ridges around the pre-Cambrian volcanic core, exposed at Accomac and in the valley to the southwest. Similarly it is overthrust on its west side along the northeast continuation of the Glades thrust fault, which joins the Chickies overthrust at the river. The conglomerate on the northwest limb is strongly overturned to the northwest, adjacent to the thrust fault, dipping 55°–35° SE. A normal fault, called the Highmount fault, bounds the southeast side of the fold and drops the Harpers phyllite against the Hellam conglomerate and pre-Cambrian volcanic rocks, just as it does in the Mount Zion fold. A small triangular mass of Chickies quartzite is caught in a fault block east of Highmount. The Accomac anticline appears to be an anticlinal horst,[33] bounded on both sides by normal faults with downthrow away from the axis, which is further cut at the south by two cross faults that break it into quadrangular blocks, which have suffered differential movement in the later adjustment. (See fig. 12.)

The Chickies anticline is a fold of Chickies quartzite cut through by the Susquehanna River and represented by the east end of the Hellam Hills and by Chickies Rock, on opposite sides of the river. (See pl. 2.) East of Accomac the Highmount normal fault offsets it from the core of the Accomac, of which it is the eastern extension. It trends more eastward than the Accomac anticline and is not so highly uplifted as at Accomac and therefore does not expose beds below the massive quartzite of the Chickies formation. Minor folding on the south flank of the anticline is indicated not only by the wide belt of Harpers phyllite but by sharp anticlines of Chickies quartzite exposed in the river bluff. (See pl. 4, *B*.) They are all overturned toward the northwest and are broken by minor thrust faults. The schistosity is invariably southeast and in places obscures the bedding. Details of these faulted folds may be seen on both sides of the river.

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[33] Stose, G. W., New type of structure in the Appalachians: Geol. Soc. America Bull., vol. 35, pp. 465–480, 1924.

The Trout Run anticline is a broad uplift of Chickies quartzite which forms the high hills that surround Trout Run. It is the western part of the Hellam Hills anticlinorium. At Codorus Creek the Chickies quartzite dips westward beneath the Harpers phyllite, and the phyllite is seen to be almost horizontal on Dee Run and Codorus Creek. On the north side of the anticline excellent exposures along the river bluffs show the lower beds of the quartzite to be closely folded and overturned, and these minor folds are recumbent and broken and cut off by thrust faults. These minor broken anticlines are slices of the larger overthrust mass, the thrust plane of which lies in the river on the north side of the anticline. This thrust fault enters the Middletown quadrangle north of Chickies Ridge and is called the Chickies overthrust. It follows the river from Chickies Rock to the mouth of Codorus Creek, where it is obscured by normal faulting and passes under the Triassic rocks south of Mount Wolf. The closely folded and overturned rocks of the Trout Run, Accomac, and Chickies anticlinal masses are thrust along this fault over the more gently folded rocks in the Marietta anticline.

EMIGSVILLE SYNCLINE

The syncline south of Emigsville incloses a large area of Vintage dolomite almost symmetrically surrounded by hills of Antietam quartzite gently dipping into the syncline. It rises eastward, and a branch of it passes between the Trout Run and Mount Zion anticlines. Southwestward it deepens and contains a "klippe" of inverted Kinzers formation on the northern edge of the Glades overthrust.

WRIGHTSVILLE SYNCLINE

A syncline forming the York limestone valley lies between the Hellam Hills anticlinorium and the Mount Pisgah anticline. The Lower Cambrian limestones that dip into the syncline from the north are covered by the Conestoga limestone, of Ordovician age, which overlaps them on the south side of the valley. Along the southeast edge of the valley it is bounded by the Stoner overthrust, which lies on the north side of the Pisgah anticline.

MOUNT PISGAH AND STRICKLER ANTICLINES

The Mount Pisgah anticline crosses the southeast corner of the quadrangle. The Hellam conglomerate basal member is exposed at the axis of the fold and forms the high part of the hills in the southern part of the quadrangle and at Mount Pisgah, in the York quadrangle. The slate and thin quartzite of the Chickies formation above the Hellam member are exposed at the axis to the southwest; thicker quartzite layers higher in the formation show on both flanks.

The anticline is thrust northwestward along the Stoner thrust fault, which cuts diagonally across the structure just east of Strickler station, where the Mount Pisgah anticline is thrust across the end of a symmetrical anticline, which may be called the Strickler anticline. This fold is cut through by the Susquehanna River, and in the river bluff Antietam quartzite with Vintage dolomite on both flanks is exposed. East of the river, in the Lancaster quadrangle, a narrow synclinal limestone valley lies between the Manor Hills anticline, the eastern extension of the Mount Pisgah anticline, and the Strickler anticline.

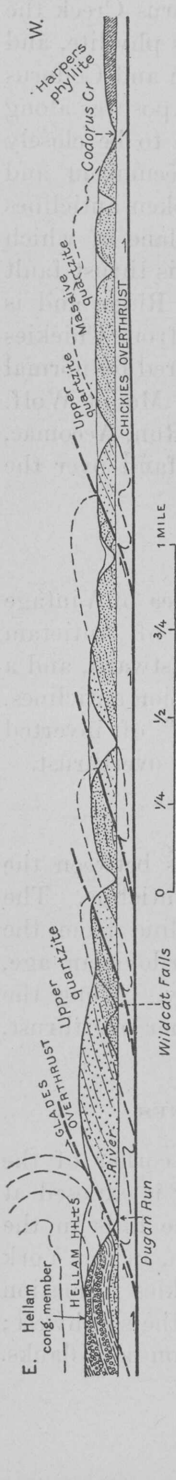


FIGURE 13.—Structure in Cambrian rocks in river bluff west of Dugan Run, as seen from the river. Shows minor overturned folds of Chickies quartzite broken and faulted, forming slices of the main Chickies overthrust

MARIETTA ANTICLINE

The Marietta anticline is a long, narrow fold that barely brings the Antietam quartzite to the surface for 2 or 3 miles along its axis at Marietta. The Vintage and Ledger dolomites surround the Antietam in regular order on the north side and the east end, but outcrops on the south limb are hidden by the cover of river gravel. The fold is apparently broken on the south side by a minor normal fault, shown by the offset of formations east of Marietta. The limestones on the north limb of the fold dip northward in a broad monocline with minor folding, and Ordovician limestone passes beneath the Cocalico shale east of Rheems. These formations are diagonally overlapped on the west by Triassic red sandstone.

THRUST FAULTS

Chickies overthrust.—The Chickies overthrust enters the quadrangle east of Chickies and lies in the river beyond its sharp bend westward above Chickies Rock. The thrust fault has an east-west trend, which is diagonal to the trend of the folds, so that beds in the Chickies Rock, Accomac, and Trout Run anticlines are truncated by the fault. This diagonal movement is in part a thrust and in part a horizontal shear across the bedding. At Accomac the trend of the Accomac anticline is much more diagonal to the thrust fault than that of the folds farther east. West of Dugan Run many minor overturned and recumbent folds of the massive quartzite beds of the Chickies on the north limb of the Trout Run anticline are exposed in the river bluff. Each fold is broken and overthrust, forming slices of the main overthrust mass, and these minor thrust planes pass diagonally into the Chickies thrust plane below. (See fig. 13.) These minor anticlines plunge and die out southwestward in the main Trout Run uplift and probably are the result of the diagonal movement along the Chickies overthrust.

The Chickies overthrust is obscured by normal faulting near the mouth of Codorus Creek and apparently lies in the Harpers phyllite south of Saginaw. Westward it lies along the northern edge of the block of Chickies quartzite and Harpers phyllite northwest of Starview and apparently passes under Triassic rocks 1 mile south of Mount Wolf.

Glades overthrust.—The Glades overthrust follows the northwest side of the Accomac-Mount Zion anticline from Dugan Run to a point west of Pleasureville. The Hellam conglomerate member of the Chickies formation lies on the front edge of the thrust mass west of Accomac and Highmount and southwestward to Glades. The thrust block overrides Chickies quartzite and Harpers phyllite of the Trout Run anticline. A little west of Glades the thrust rises to higher beds of the Mount Zion anticline—the Chickies quartzite, Harpers phyllite, and Antietam quartzite—which are thrust over Vintage dolomite of the Emigsville syncline. West of Pleasureville the fault swings sharply north around the east end of the shale hill of the Kinzers formation north of Myers Mill and then continues its southwestward course along the northwest foot of the shale hill. The Kinzers formation here is inverted, its upper limestone member dipping 15°–25° SE. beneath the lower shale member, and this beneath the Vintage dolomite to the south of the shale hill. The Ledger dolomite exposed at the Emigsville road near the southwest corner of the quadrangle is apparently part of the overridden block where the overthrust mass has been worn through. The hill of Kinzers formation and the Vintage dolomite on its south side are part of an overturned anticline which has been thrust northwestward over the Emigsville syncline. (See fig. 14.) It is a nearly detached portion of the Glades overthrust mass (a "klippe"), which is here a recumbent anticline, the overturned beds of which have a nearly horizontal attitude. The overthrust has ridden on a flat thrust plane over the Trout Run anticline and other structural features north of the York Valley.

Stoner overthrust.—The Stoner overthrust fault lies on the south side of the York Valley, but the fault is not clearly evident in the vicinity of Stoner station, where the contact of Harpers phyllite and Conestoga limestone could be due to overlap of the Conestoga on the Harpers, as the Conestoga is known to be an unconformable formation. East of Strickler station, however, this fault cuts off the Strickler anticline, which enters the quadrangle from the Lancaster quadrangle, where its east end plunges under Conestoga limestone south of Mountville. In the river gorge the lower beds of the Chickies in the Mount Pisgah anticline of the Stoner overthrust mass are thrust against the Conestoga limestone in the compressed syncline on the south side of the Strickler anticline, and therefore it is evident that this fault represents considerable horizontal shortening.

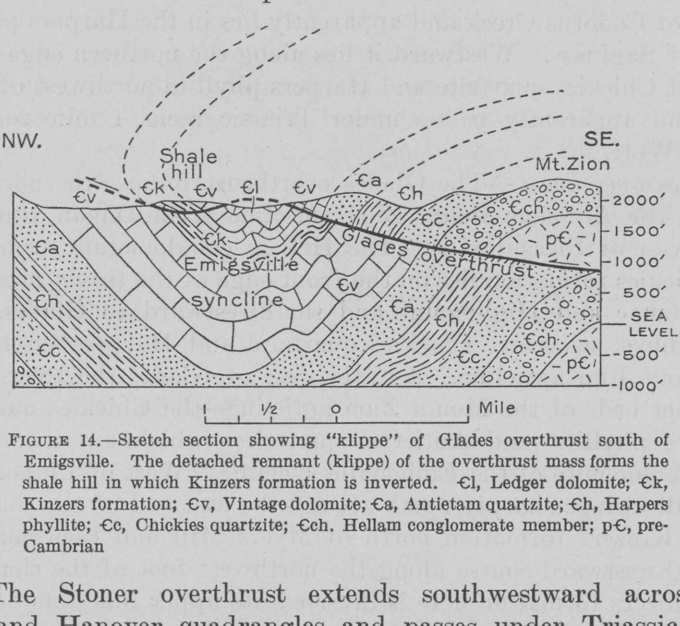


FIGURE 14.—Sketch section showing "klippe" of Glades overthrust south of Emigsville. The detached remnant (klippe) of the overthrust mass forms the shale hill in which Kinzers formation is inverted. Ɛl, Ledger dolomite; Ɛk, Kinzers formation; Ɛv, Vintage dolomite; Ɛa, Antietam quartzite; Ɛh, Harpers phyllite; Ɛc, Chickies quartzite; Ɛch. Hellam conglomerate member; pƐ, pre-Cambrian

ing. The Stoner overthrust extends southwestward across the York and Hanover quadrangles and passes under Triassic rocks southwest of Hanover.

NORMAL FAULTS

The Paleozoic rocks are cut by many straight normal faults, which fall into two general classes—those that follow the strike of the Paleozoic rocks and have a northeasterly trend and those that cut across the strike and generally have a northwesterly trend. Some of those that are parallel to the strike lie on the flanks of anticlines and have the down-throw away from the axis, and such structures are in the nature of anticlinal horsts. Most of the faults that parallel the strike are on the south flanks of anticlinal folds and have the downthrow to the south. The chief normal fault of this character borders the south side of the Mount Zion and Accomac anticlines and is called the Highmount fault. On the flank of the Accomac anticline it trends south-southwestward, parallel with the axis of the fold, and on the flank of the Mount Zion anticline it trends west-southwestward, parallel to the Mount Zion axis. A cross fault occurs at the southwestward curve in the strike and separates the two parts of the anticline. Along the Highmount fault the Harpers phyllite is dropped against the Hellam conglomerate and in places against pre-Cambrian volcanic rocks, with a throw of at least 1,000 feet. At the westward-plunging end of the Mount Zion anticline the Highmount fault is offset a short distance northward by a cross fault south of the Middletown quadrangle, but it continues southwestward again along the axis of the fold. (See fig. 12.) The downthrow here brings the Vintage dolomite south of the fault against the Chickies quartzite just east of Codorus Creek, with a vertical displacement of perhaps 1,500 feet. A normal fault parallel to the Highmount fault but with the downthrow in the opposite direction lies on the northwest flank of the Accomac anticline. The downthrow on these two faults is away from the axis.

The Accomac anticline is also cut by two nearly east-west cross faults which, with the Highmount and its parallel fault, divide the anticlinal mass into two rhomboidal blocks. The cross faults are apparently of small throw and later than the northeasterly faults, which they displace. Another cross fault, which cuts through the Mount Zion anticline at Pleasureville, extends southeastward as far as Dallastown in the York quadrangle. These faults are associated with other faults near Emigsville and Starview which cut and offset the Triassic rocks to the west, and the movement on them was therefore, at least in part, post-Triassic.

METAMORPHISM

In the southern part of the Middletown area the folding and faulting were accompanied by metamorphism. The limestones are crystalline and in the York Valley the softer beds of the Conestoga limestone have a strong slaty cleavage with development of sericite on the planes of schistosity. The Chickies quartzite is firmly cemented, but because of its original purity it is not a satisfactory index of metamorphic intensity; more can be gained from a study of the more argillaceous rocks.

The Hellam conglomerate of the Hellam anticline contains muscovite developed parallel to the cleavage. The rock is a coarse to fine-grained schistose conglomerate which in thin sections shows quartz grains partly granulated and with undulatory extinction. The ground mass is composed of fine quartz and of muscovite with strong dimensional parallelism. Feldspar grains (microcline) are cracked and dusted with hematite and magnetite. The rock has undergone low-rank metamorphism, as is shown in the cataclastic texture of quartz and feldspar and by the crystallization of muscovite, a low-temperature mineral. The Harpers phyllite of the Hellam and Strickler anticlines also shows low-rank metamorphism. It is a fine-grained aggregate of quartz and feldspar with felty muscovite and fine biotite and contains grains of apatite and zircon and magnetite porphyroblasts.

The Lower Cambrian rocks of the Pisgah anticline are more metamorphosed than those to the north of it. The Chickies slate is crystalloblastic and the Harpers and Antietam formations on the south side of the anticline just south of the Middletown quadrangle are fine-grained schists. The Harpers schist in thin section shows fine quartz and feldspar with muscovite developed parallel to the cleavage. It contains also coarser muscovite blades and ilmenite porphyroblasts. The Antietam quartz schist of the Pisgah anticline is coarser grained than the Harpers schist and contains brown biotite porphyroblasts with zircon inclusions surrounded by pleochroic halos.

Biotite is a mineral formed only at high temperature and indicates more intense metamorphism than chlorite or muscovite. The metamorphism above described is progressive metamorphism that took place during the folding. The heat necessary to effect such metamorphism was generated at considerable depth and perhaps was increased by rapid folding during strong differential pressure. Another source of heat for metamorphism besides depth and lateral pressure is deep batholithic intrusion, and such a cause has been suggested [34] to explain the intense metamorphism of Paleozoic rocks around Mine Ridge and farther southeast, but except for the presence of tourmaline in the rocks no evidence of batholithic intrusion has been found in this area.

It has been stated [35] that "where Paleozoic and pre-Cambrian rocks reappear in the area of the Reading Hills intense metamorphism is confined to the oldest pre-Cambrian rocks." It is evident, therefore, that the metamorphism wanes rapidly to the northwest. If the heat necessary for metamorphism in this area is not due to a subjacent batholith, it must be concluded that depth of burial during folding was greater for the Lower Cambrian rocks of the southern Middletown area than in the region to the northwest.

AGE OF THE DEFORMATION

Folding and thrust faulting.—The Paleozoic rocks in this region were deposited in horizontal layers in the southeastern part of the Appalachian geosyncline, a shallow sea in which sedimentation was continuous, although fluctuating, from the Lower Cambrian to the close of the Carboniferous. The last record of this sedimentation

[34] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district, Pa.: U. S. Geol. Survey Bull. 799, pp. 137–139, 1929.

[35] Idem, p. 129.

now preserved in the Middletown area is late Ordovician in age. The Paleozoic rocks of the Middletown quadrangle have been closely folded, the folds are overthrust to the northwest and the limbs of some of the anticlines are broken and thrust northwestward over the adjacent synclines. The Chickies, Glades, and Stoner overthrusts represent such broken folds. The rocks were metamorphosed at the same time that they were folded, with development of new textures and new minerals. Cleavage or foliation was developed across the folded bedding planes and for the most part dips steeply southeast at various angles. This cleavage strikes parallel to the axes of the folding and at right angles to the direction of the pressure that produced it.

The question arises as to the time when this deformation took place. The folded rocks of the Middletown area lie in the southeastern part of the folded Appalachian belt. In western Pennsylvania, where Pennsylvanian and early Permian rocks are involved in Appalachian folding, the major crustal deformation is known to have occurred near the end of the Paleozoic. In the Middletown area minor folding and erosion are recorded in post-Beekmantown time, and to the northeast in the Lebanon Valley similar movement and erosion preceded Silurian deposition. There is no evidence, however, that intense folding and metamorphism comparable to that of the Taconic mountain making in New England affected Pennsylvania at the end of Ordovician time.

The folding in the Middletown area is of the same type of close folding as in the Appalachian region to the west, and the direction of the folds is parallel to that of the curving folds known to be of late Paleozoic age. It seems reasonably certain, therefore, that the folding in the Middletown area was also of late Paleozoic age.

Normal faulting.—It is believed that after the compressive stresses that produced the Appalachian folding were relieved by the yielding of the rocks there was a period preceding the Triassic in which tensional strains probably occurred in the rocks and produced broad warping accompanied by a settling of blocks by gravitative adjustment. Extensive normal faulting of this kind is known to have taken place at the end of the Triassic period, for the late Triassic rocks that are present in the northern part of this and adjacent quadrangles are broken and faulted by such normal faults, and many of these faults extend into the adjacent Paleozoic rocks.

AREA OF TRIASSIC ROCKS

The folds in the Paleozoic rocks in the northern part of the quadrangle are concealed by the cover of Triassic rocks, so that only the later deformation that affected these younger rocks can be traced in that area. The Triassic rocks lie in a northwestward-tilted block, depressed on its northwest edge along a series of normal faults that bound them on that side. These boundary faults cut off the Triassic area in the southern part of the Hummelstown quadrangle, 2 to 4 miles north of the Middletown quadrangle, but enter the northwest corner of the Middletown quadrangle west of Waltonville. The Paleozoic limestone in the northwest corner of the quadrangle is part of the uplifted block that forms the Lebanon Valley, which lies north of the Triassic boundary faults.

The northern edge of the faulted and tilted Triassic block is broken into several small blocks by minor faults that trend in a northerly direction and intersect and offset the boundary faults, so that the northwest edge of the Triassic is very irregular in outline. These minor faults extend into the Middletown quadrangle and seem to terminate in a fault that extends across the quadrangle in a southwesterly direction, passing near Deodate. This fault cuts through and offsets the intrusive diabase bodies at Deodate and Swatara Hill. Likewise the minor northward-trending faults cut and offset the Deodate intrusive mass at Bachmanville School, at Bachmanville, and 2 miles east of Bachmanville. Another northeastward-trending fault cuts the thick Yorkhaven-Newville diabase sheet near the river and offsets it, and a smaller fault to the west also affects the sheet. To account for the apparent lack of accord of the outcrops of the base of the Triassic on opposite shores of the river a fault is postulated along the river.

GEOLOGIC HISTORY

The earliest geologic record of this area is preserved in the volcanic rocks exposed in the Hellam Hills. They show that in later pre-Cambrian time extensive flows of both basaltic and rhyolitic lavas were poured out over the region. These lavas are known to have been spread over a vast area of what is now southern Pennsylvania, Maryland, Virginia, and North Carolina. In places these lavas are seen to rest on older crystalline rocks, including both sedimentary rocks and igneous intrusives, which represent the floor on which the lavas were poured out. These old rocks, including the lavas, were later intensely compressed, crumpled, and crushed by mountain-making forces, and before the end of pre-Cambrian time they were eroded to a relatively gentle surface.

At the beginning of Cambrian time a part of the region was depressed so that it was invaded by an arm of the sea in which were deposited marine sediments—first coarse waste products from the disintegration of the crystalline rocks, forming arkose, coarse sandstone, and conglomerate; then finer sandy and argillaceous material, forming shale and sandstone. These beds were later hardened into the quartzites, phyllites, slates, and conglomerates beginning with the Hellam conglomerate and ending with the Antietam quartzite.

There were animals living in this early sea, for remains of trilobites and shells are sparingly preserved in the calcareous sandstone of the Antietam, and many of the beds of quartzite have plentiful fossil tubes of the sea worm *Scolithus linearis.* When coarse waste material ceased to be washed into the sea, limy and dolomitic mud and silt were accumulated on the floor of the sea and were later hardened into limestones, dolomites, and calcareous shales, certain layers of which contain beautifully preserved fossil trilobites and shells, remains of animals that lived in this early sea.

Limy and dolomitic mud accumulated in the sea almost continuously throughout the rest of the Cambrian period and into the Ordovician period, and these beds are now represented by the great thickness of hard dolomite and limestone formations from Tomstown dolomite to Beekmantown limestone. At the end of Beekmantown time the southeastern part of the area was uplifted and some of the previously deposited sediments were worn off, so that when the region was again submerged, impure argillaceous and carbonaceous limy mud was spread over the eroded edges of these older beds and now forms the unconformable Conestoga limestone, of post-Beekmantown (Ordovician) age. However, large amounts of dark argillaceous material did not reach the basin until still later in Ordovician time, when the Cocalico shale was deposited in the northern part of the region.

Because no sediments of Paleozoic age younger than Cocalico are preserved in this area there is no direct evidence that they were ever deposited there, although thick deposits of sand, shale, and some limestone were laid down during later Paleozoic time only a short distance to the northwest. These deposits consist of a hard sandstone of Silurian age which makes mountain ridges, highly ferruginous beds of Clinton age which are locally iron-ore deposits, highly fossiliferous softer black shales and harder sandstones of Devonian age which form valleys and low ridges, and coal-bearing formations of Carboniferous age.

Late in Paleozoic time mountain-making forces again compressed the rocks and folded the flat-lying sedimentary formations into elongated troughs and arches several thousand feet high and extending many miles in a northeasterly direction. The Hellam Hills anticlinorium is an example of such a great arch. Many folds were broken under the intense compression, and some of the breaks culminated in great overthrust faults, such as the Chickies overthrust.

After the late Paleozoic mountain making, during which compression had been relieved by folding and overthrusting, large blocks of the region settled along nearly vertical joint planes, resulting in normal faulting and tilting of blocks, which formed a vast sunken basin or trough with a northeast trend and a highland to the southeast. In the following Triassic period torrential rains washed the waste from the disintegrated crystalline rocks on this highland into the trough, and arkosic sand, argillaceous sand, and fine sandy mud accumulated. Much of this sediment was of a pronounced red color, owing to the fact that the iron content of the rocks was highly oxidized when they disintegrated, apparently under arid conditions. After the accumulation of a thickness of many thousands of feet of these red rocks, which now form the Newark group, further adjustment of earth blocks by tilting and normal faulting took place on a still larger scale than before, and in places mountains were formed on the northwest side of the basin by differential uplift of several thousand feet. Catoctin Mountain, in southern Pennsylvania, is an example.

Since the end of the Triassic period, the region has been continuously subjected to erosion. During Jurassic time the wearing down of high points was so intense and prolonged that the region apparently was largely reduced to a gently rolling surface near sea level, called a peneplain. Since the beginning of Cretaceous time the Appalachian region has been slowly rising, with intervals of rest and minor subsidence, forming an elongated domed surface, the dissection of which has produced the present Applachian Mountains. The softer rocks, which were removed most readily, form the valleys; the harder rocks, which were least eroded, are left as mountains; and rocks of intermediate hardness form lower hills and slopes. Even the hardest rocks were cut through in places by the major streams, forming rocky gaps, such as the gap between Chickies Rock and Hellam Point through which the Susquehanna River flows. The uplift of the land was spasmodic, so that the down-cutting of the streams produced a surface that showed rhythmic steps, which are now preserved in remnants of high-level surfaces or peneplains and several gravel-covered terraces at lower levels bordering the river, which are stepped downward toward the valley.

MINERAL RESOURCES

The mineral resources of the Middletown quadrangle comprise limestone, clay, sandstone, baked shale, sand, and gravel. One-third of the area is occupied by limestone, which is extensively quarried at places for crushed stone, flux, and lime. Clay derived from Triassic red shale is used for making bricks. Triassic sandstone furnishes excellent building stone and building sand. The Chickies quartzite also is quarried for sand. A crushed stone of great toughness is produced from Triassic baked shale. The region produced considerable brown iron ore in the past, but none of the deposits have been worked recently. Small veins of asbestos occur in the metabasalt, but the asbestos is not plentiful enough to be of commercial value.

LIMESTONE

Pure limestone is composed of calcium carbonate, but few limestones are pure; they usually contain varying amounts of magnesia, silica, iron, and alumina. When the magnesium carbonate content is 45 per cent the rock is called dolomite, but rock containing much less magnesia is also classed as dolomite, or more correctly as high-magnesium limestone, in contrast to calcite, or high-calcium limestone.

The oldest limestone formations, the Vintage and Ledger, contain more dolomitic material than the younger Conococheague, Beekmantown, and Conestoga limestones. The active lime and crushed stone quarries are in the Ledger dolomite and Beekmantown limestone. Those formerly active were for the most part in the Ledger dolomite and Conestoga limestone.

In general the Ledger dolomite is the purest carbonate rock in the region, most of its beds being essentially free from silica and alumina. It was probably deposited as a pure calcium carbonate but has since been largely altered to dolomite through the substitution of magnesium for part of the calcium by chemical change. Various stages of this gradual alteration have been observed in quarries in the region, where the less crystalline blue limestone is seen to pass into more highly crystalline white marble and eventually into coarsely crystalline dolomite, the alteration taking place first along crevices and spreading from them throughout the rock, the rounded unaltered residual masses giving it the appearance of a conglomerate. The pure calcium limestone of the Ledger is much sought for.

Uses of limestone.—Limestone is extensively used for many purposes, only a few of which can be mentioned here. Its largest and perhaps its most important use is as crushed stone for road material, ballast, and concrete. Other uses include fertilizer in agriculture, both in the form of ground limestone and burned lime; burned lime and hydrated lime for mortar plaster; flux in the manufacture of iron and steel; and building stone, including curbing and flagging. It has a continually increasing use in the manufacture of Portland cement. Dead-burned dolomite furnishes refractory furnace linings and bottoms and is also used in the manufacture of magnesia products.

All the active limestone quarries in the Middletown area produce crushed stone, but in two plants burned lime is the main product. The crushed stone is used for road material, for concrete in roads, bridges, and other structures, in concrete blocks, and as railroad ballast. Limestone is used somewhat for building stone but not so much as formerly, as cement blocks and concrete have taken its place, especially in bridges and foundations of buildings. The only plant engaged in the manufacture of concrete blocks in the Middletown area is that of Strickler & Hinkle, 2 miles east of Marietta.

The Middletown quadrangle is crossed by a network of primary and secondary State highways which were built and are maintained from the supply of local crushed stone.

The Lincoln Highway (route 30) crosses the southeastern part of the quadrangle and passes through Wrightsville southwestward along the York Valley. It is built of crushed stone with a bituminous binder. Highway 24, extending from York to Harrisburg by way of Yorkhaven, which crosses the western part of the quadrangle, is of the same type. The main route from York to Harrisburg is the Susquehanna Trail (route 111) which lies west of route 24 and which is built of concrete. Route 230 from Lancaster to Harrisburg is a concrete road to Elizabethtown and bituminous macadam thence to the northwest. Highway 241 crosses it at Elizabethtown, passing northeastward through Lawn and Colebrook to Lebanon, northeast of this area, and south to Bainbridge and Marietta. Route 441, which connects Bainbridge with Middletown, is surfaced only with crushed stone. Connecting roads that extend from Elizabethtown through Deodate to Hershey, in the Hummelstown quadrangle, from Elizabethtown to Maytown, and from Mount Joy to Maytown are surfaced with bituminous macadam.

The State Highway Department has supplied the following data concerning the stone in the active quarries:

Results of tests of stone from Middletown quadrangle

No. on map	Owner or producer	Type of rock	Specific gravity	Weight per cubic foot (pounds)	Absorption (pounds per cubic foot)	Water (per cent)	Toughness [a]	Crushing strength (pounds to the square inch)
7	Penn Limestone & Cement Co.	Limestone	2.78	172.5	0.22	3.4	10	25,782
10	Strickler & Hinkle	do	2.85	177.8	.47	4.0	9	20,448
14	J. E. Baker & Co., Northwest quarry, Bainbridge.	Dolomite	2.78	174.0	.18	2.06	9	34,838
16	J. E. Baker & Co., Mount Wolf quarry.	do	2.70	168.5	.37	2.9	10	13,840
5	Heisey Bros	Baked shale	2.83	176.6	.12	1.4	39	25,891

[a] Height in centimeters from which a 2-kilogram hammer must be dropped to crush the rock.

Lime is burned in the modern plants of J. E. Baker & Co., one near Bainbridge and another at Saginaw. This lime is largely shipped out of the region for industrial purposes. Farmers no longer burn limestone from local quarries for fertilizer.

There are no Portland-cement plants within the Middletown area, but near the main line of the Pennsylvania Railroad are deposits of limestone and shale suitable for the manufacture of cement. The Beekmantown limestone, which this railroad crosses between Mount Joy and Rheems, contains near Florin beds of pure limestone overlain by Cocalico shale, which are also suitable for the manufacture of cement. The " cement rock " or Leesport limestone so largely quarried for cement in the Lehigh Valley is not present in this area between the Beekmantown limestone and Cocalico shale but a proper mixture of the two formations should produce a good Portland-cement material.

Analyses of limestone and dolomite from Middletown quadrangle

	Beekmantown limestone							
	1	2	3a	3b	3c	3d	4a	4b
SiO_2	0.75	2.47	1.24	1.81	0.92	1.19	1.45	5.84
Al_2O_3	1.09	.99	.81	.95	.75	.51	.61	1.93
Fe_2O_3								
$CaCO_3$	94.87	78.70	83.50	83.76	85.10	91.88	90.99	72.30
$MgCO_3$	2.63	17.71	14.36	13.15	12.92	5.89	6.60	19.85
S	.015	-------	.063	.063	.063	.063	.041	.041
P	.004	-------	.008	.008	.008	.008	.006	.006
	99.359	99.87	99.981	99.741	99.761	99.541	99.697	99.967

	Conococheague limestone				Ledger dolomite				
	5	6a	6b	6c	7	8a	8b	8c	8d
SiO_2	8.02	5.36	14.54	3.20	3.62	-------	-------	-------	-------
Al_2O_3	1.63	1.84	5.18	1.04	1.92	0.517	0.304	0.869	0.731
Fe_2O_3									
$CaCO_3$	78.96	72.21	63.88	71.82	52.14	54.75	55.104	53.17	50.339
$MgCO_3$	-------	20.29	-------	24.47	42.01	44.204	43.602	43.522	41.143
S	-------	-------	-------	-------	-------	.011	.023	.021	.030
P	-------	-------	-------	-------	-------	.006	.010	.014	.029
	88.61	99.70	83.60	100.73	99.69	99.488	99.043	97.596	92.272

	Ledger dolomite—Continued				Conestoga limestone				Vintage dolomite
	9	10	11a	11b	12	13a	13b	13c	14
SiO_2	2.05	1.68	1.10	1.25	3.43	-------	-------	-------	1.40
Al_2O_3	1.32	1.09	.085	1.05	.26	-------	-------	-------	.06
Fe_2O_3					.59	4.05	0.82	26.07	.64
$CaCO_3$	54.63	54.93	55.05	92.70	61.15	93.49	98.04	64.99	70.64
$MgCO_3$	42.10	41.82	42.00	5.00	33.55	2.61	1.86	6.40	25.80
S	-------	-------	-------	-------	.006	-------	-------	-------	Trace.
P	-------	-------	-------	-------	.034	-------	-------	-------	.022
	100.10	99.52	98.235	100.00	99.020	100.15	100.72	97.46	98.562

1. On property of J. A. Hipple, ⅔ mile north of Rheems.
2. Old Hipple quarry (east of No. 7).
3a–3d. Penn Limestone & Cement Co. (No. 7), ½ mile north of Rheems.
4a–4b. H. K. Landis Stone Meal Co. (No. 9), 1½ miles south of Rheems.
5. Brubaker farm, 1¼ miles north of Maytown.
6a–6c. Left bank of Little Chickies Creek, 1½ miles south of Mount Joy.
7. Rowenna (No. 12).
8. Haldeman's quarry (No. 44) at Chickies: a, South quarry, best blue limestone, fine grained, brittle, light blue-gray; b, South quarry, coarse grained, hard, brittle, light gray; c, North quarry, hard, blue-gray, tough; d, North quarry, sandy layer.
9. Two-thirds mile north of Chickies, southeast of Chickies Creek.
10. Junction of Chickies and Little Chickies Creeks.
11. Mount Wolf quarry, J. E. Baker & Co. (No. 16), Saginaw: a, Low-silica dolomite; b, high-calcium rock.
12. Beard Lime Co. (No. 46), Wrightsville (not now active); average of 10 samples.
13. Wrightsville Stone & Lime Co. (No. 23), Stoner station (inactive): a, Limestone conglomerate; b, best stone in limestone conglomerate; c, shaly layers.
14. Emigsville Limestone Co. (No. 25), Emigsville (inactive); average of 7 samples.

Analyses 1–7, 9, 10, 12, 14 by Bethlehem Steel Co.; 8a–8d by A. S. McCreath (Pennsylvania Second Geol. Survey Rept. M2, p. 309, 1879); 11 by J. E. Baker & Co.; 13 by J. W. Kellogg.

Active quarries.—The limestone areas of the Middletown quadrangle contain six active quarries and eight or more inactive quarries of considerable size. Their distribution is shown on Plate 1, and they will be described in the order of the numbers given on the map.

The quarry (No. 7) of the Penn Limestone & Cement Co., J. A. Hipple, president, 40 North Duke Street, Lancaster, is at Rheems, south of the Pennsylvania Railroad and Highway 230. It is on the site of an old quarry first operated by Jacob Stauffer and later by W. L. Heisey. It is now worked extensively for crushed stone. An old stone kiln, in which lime was burned for 30 years before 1923, and other old kilns below the quarry near the highway are still standing but are no longer used. The quarry is 100 feet deep and is worked on two levels for 1,000 feet along the strike. It is about 500 feet wide. The overburden of red clay is nowhere more than 4 feet thick in the present quarry, but an older quarry lying to the southeast of it and east of a railroad siding was abandoned in 1920 because of the amount of stripping required. The rock is much folded, and

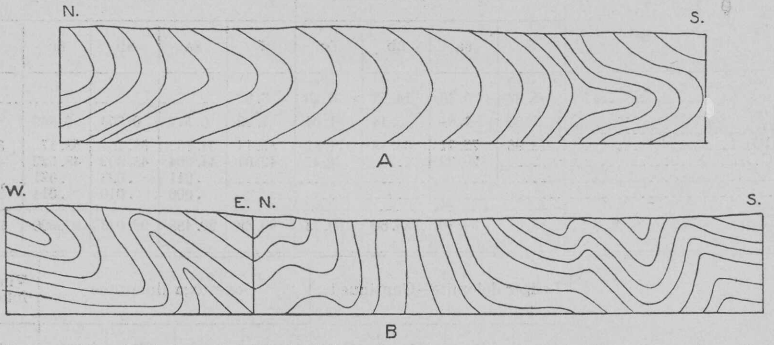
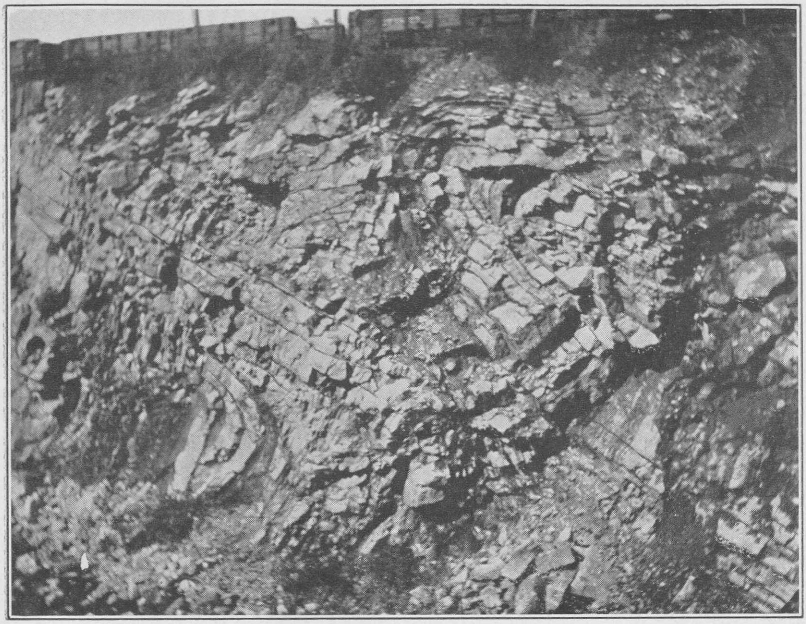
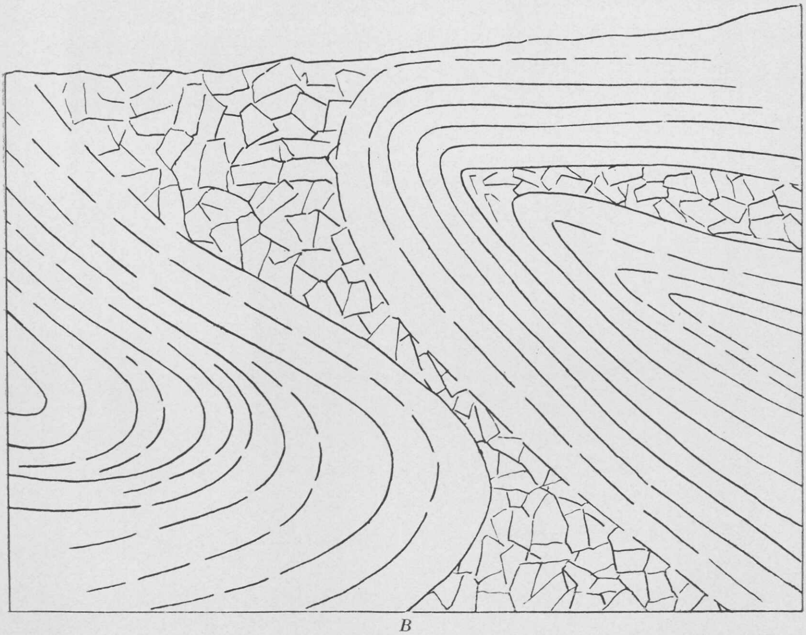


FIGURE 15.—Sketches of folds in Hipple limestone quarry. A, East face of south quarry; B, north and east faces of north quarry

an overturned recumbent fold is visible in the old quarry. (See pl. 12 and fig. 15.) The rock is a fine-grained dark-blue to gray limestone of Beekmantown age which weathers chalky. It is much veined by calcite and easily broken, and all the beds can be used. Analyses of rock from the present quarry have been made by the Bethlehem Steel Co., and 4 of them are given in the foregoing table, also 1 of the rock from the old quarry and 1 of rock from the tract owned by the company two-thirds of a mile north of Rheems. The crusher and other equipment are located at the south end of the quarry. Mules haul the cars on tracks from the two steam shovels to the elevators, but all the rest of the plant is operated by electric motors, including an electric well driller and a cyclone drill mounted on a truck, which are used on the upper levels. There are two crushers—a Bell gyratory



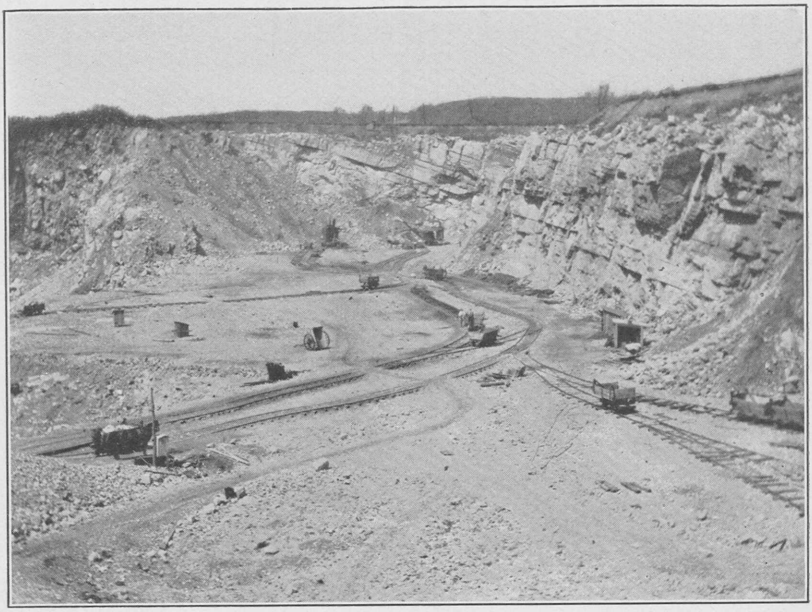
A



B

RECUMBENT FOLDS IN LIMESTONE AT ABANDONED HIPPLE QUARRY

A, Photograph. *B*, Sketch showing details of folds. Looking northwest. The axes of the folds pitch northwest.



A. MAIN PIT OF MOUNT WOLF QUARRY, SAGINAW, EXPOSING NORTHWESTWARD-DIPPING LIMESTONE

B. BAKED SHALE AT LOWER CONTACT OF DIABASE SHEET IN QUARRY NORTHEAST OF LAWN

Diabase above hammer.

crusher and a Blake jaw crusher—which break the stone into sizes from screenings to 4-inch, which is used for ballast. Three elevators carry the product to large bins. New Holland rolls for making pulverized limestone were installed in 1928. The daily capacity is 600 to 700 tons of crushed stone, which is shipped in trucks to Lancaster, Elizabethtown, and other near-by points. In 1927 the quarry supplied part of the stone for a new concrete surface of the Lincoln Highway east of Lancaster.

Two miles south of Rheems there is another active quarry (No. 9), also in Beekmantown limestone, belonging to the H. K. Landis Stone Meal Co. The quarry is 50 feet square and about 25 feet deep and is equipped with tracks, crusher plant, and bins. There are three crushers and rolls, and the chief product is crushed stone, which is marketed by trucks. Pulverized limestone, which passes through 50 to 200 mesh screen, is prepared and used for fertilizer. The rock of the quarry is white to dove-colored marble lying in an anticline. Two analyses of the rock from this quarry are shown in the table.

An active quarry (No. 10) in the Ledger dolomite a mile north of Chickies, on the left bank of Donegal Creek, is owned by Strickler Hinkle, of Maytown, and has been in operation since 1920. Its product is largely crushed stone, but some of the fine material is used for making cement building blocks in a plant located at the quarry. The quarry is about 300 feet square, and the newest opening in 1928 on the east side of the quarry is about 15 feet deep and 30 feet square, with little over-burden. The rock is worked by hand, loaded in cars on tracks, and is hauled by horses to the cable that carries the rock to the crushers, of which there are three—a Champion jaw crusher and two disk crushers. A portable steam tractor furnishes power to operate the crushers and an air compressor and pump for removing water from the quarry when the water level is high. The product is made in four sizes, from three-fourths inch to 2 inches, and is shipped by truck. In 1928 the quarry supplied stone for the new concrete bridge over Chickies and Donegal Creeks on Highway 24. The company produces about 4,000 cement blocks yearly. The rock of the quarry is a hard dark-blue to gray dolomite which weathers light, underlain by hackly fine light-gray dolomite. No analyses are available, but analyses 9 to 11 in the table give the composition of Ledger dolomite of the near-by area. The analyses show a high percentage of magnesium carbonate as compared with the amount in the Beekmantown limestone.

J. E. Baker & Co., of 114 North George Street, York, operate three quarries in the Middletown quadrangle, all on the Susquehanna River—two at Billmeyer, called the Bainbridge quarries, and the Mount Wolf quarry, at Saginaw, across the river. Two of the quarries are in the Ledger dolomite, but the southeastern quarry at Billmeyer, called the Princess quarry, is in high-calcium rock probably in the Vintage formation.

The Princess quarry (No. 13) is an opening 300 feet across and 1,000 feet long in the direction of the strike and has a face 100 feet high on the northwest side, where the dip is 40° N. Horse-drawn cars operate on tracks that converge from all parts of the quarry floor to the cableway, which carries the rock to the crusher and kilns, at the west end of the quarry. The pure rock is burned in five flame kilns and is passed through a Clyde batch hydrator to produce Victor bagged lime. Quicklime in lumps forms a small part of the product. The high-calcium rock is a dark-blue to buff and mottled blue-gray limestone that is reported to run 95 per cent calcium carbonate, although no analysis is available. The high-calcium lime is used for glass and soap manufacture and mason's lime. The impure layers are crushed for broken stone.

The northwestern quarry at Billmeyer (No. 14) is a large open pit half a mile northwest of quarry 13 and north of the crushers, kilns, and boiler house, which are along the tracks of the Pennsylvania Railroad. It is operated for high-magnesium, low-silica dolomite. In 1927 the total number of kilns in operation at this quarry was 10 pot kilns and 62 flame kilns. The rock is a mottled blue hard even-grained dolomite and dips 55°–80° N. The product is dead-burned dolomite for lining open-hearth furnaces and crushed stone for road material. Dolomite for the former purpose should contain over 40 per cent magnesium carbonate. It is dead burned and then passed through a 12-inch McCalley crusher, which produces 3-inch lumps, and is shipped by the Pennsylvania Railroad to steel plants in western Pennsylvania and elsewhere for furnace lining.

Two 125-foot rotary kilns are operated by Baker & Co. at the Kennedy quarry (No. 15), near Lobata, a mile north of Billmeyer. The quarry is abandoned and rock for the kilns is brought in from the Billmeyer quarries. These rotary kilns are continuously in operation for hydrated lime.

The Mount Wolf quarry (No. 16), at Saginaw, is near the river on a spur of the "low grade" freight line of the Pennsylvania Railroad. (See pl. 13, *A*.) It was formerly the Codorus plant of the Union Stone Co. The quarry is about 1,500 feet long parallel to the strike and 1,200 feet wide. The northwest side has a 65-foot face, where the rock dips 45° NW. The water pump and air drills are operated by an Ingersoll-Rand compressor. Horse-drawn cars operate on tracks on the floor of the quarry to take stone to the cableway. Both high-calcium, low-silica limestone and low-silica dolomite are burned in flame kilns, the former for flux and the latter for plaster, agricultural and chemical purposes, and furnace linings. Some of the rock is crushed for road material. McCalley & Simons crushers, both gyratory and disk crushers, are used to produce three sizes of road material. The crushers are run by electricity.

The Susquehanna Stone Co. opened in 1929 a quarry (No. 21) in the Vintage dolomite just south of Wrightsville. The stone was to be used for crushed stone for roads and concrete in the construction of the new highway bridge over the Susquehanna River between Wrightsville and Columbia. Crusher, screens, elevator, and large elevated bins were installed, and the quarry and plant were equipped for electric operation. The rock is a dense homogeneous fine-grained blue dolomite of the Vintage formation, which crushes to angular blocks suitable for concrete.

BAKED SHALE

Baked shale has been quarried at the upper contact of the diabase sheet half a mile north of Lawn. E. M. Keener, of Colebrook, is the owner of this quarry (No. 4), which was operated at the time Highway 241 was built. The quarry is in fine-grained diabase and hard shale. The contact with the diabase, shown in Plate 13, *B*, dips 30° NW. Here the soft red Gettysburg shale has been indurated to a hard blue shale containing magnetite, mica, and hornblende developed by the heat of the intrusive diabase sill.

A larger active quarry (No. 5), also in baked shale, is that of the Heisey Bros., 1 mile north of Elizabethtown. It is located on the south or under side of the diabase sheet, which dips 45° NW. The quarry is 200 feet long, 50 feet across, and 40 feet deep. Tracks in the bottom of the quarry extend to the hoist to the crushers, which are a New Holland No. 18 jaw crusher with rolls and an American road-machinery jaw crusher. The quarry has been operated since 1924 by the present management. The rock is hard, dense gray shale and is crushed to three-eighths inch for concrete work, and the fine product is used for top coat finishing.

SAND

Uses.—Sand is composed largely of quartz grains with other minerals in varying amounts. These impurities may be clay, lime, or iron. Sand is coarse, medium, or fine-grained and occurs as sandstone or quartzite, which has to be crushed, or as loose or crumbly sand, which can be dug and screened without crushing.

Building sand is used in concrete and mortar, in making sand-lime brick, and for the facing of concrete blocks. For this purpose it shoud be composed of silica with but little clay.

Active quarries.—The Chickies quartzite and Triassic sandstone yield building sand, but few sand quarries are being operated in the Middletown quadrangle. Heisey Bros. have a sand quarry (No. 6) just northwest of the borough line of Elizabethtown, near the old bed of the Pennsylvania Railroad. It is 20 feet square and 20 feet deep. The sand is derived from beds in the New Oxford formation, a micaceous arkosic sandstone with some gravel, dipping 30° NW. About 40 feet of fine yellow sand is workable in the quarry. A portable engine operates the machinery, which consists of a water pump, jaw crusher, rolls, and cable with conveyors that elevate the sand to the screens. The quarry is operated to meet the local demand for building sand. Another small quarry (No. 17), in New Oxford sandstone, that of Fred Doll, is east of the highway between York and Yorkhaven a mile north of Manchester. The rock is of the same type of fine yellow crumbly arkosic micaceous sandstone, dipping 15° N. A portable engine operates the New Holland crusher and rolls and other machinery. The product is building sand.

South of Chickies Rock, on the left bank of the Susquehanna, a quarry in the upper beds of the Chickies quartzite has been operated for 20 years by the Chickies Mining Co. Recently Harry and Charles Shenk have opened a quarry (No. 19) south of the larger one, and stone is brought by track and cable north to the crushers at the old quarry. The newer quarry is opened in an anticline of Chickies quartzite and overlying slate. The quartzite is blue and vitreous, is composed of quartz grains, and occurs in a 50-foot bed that dips southeast. It weathers rusty on the joints and has slate partings. The plant is equipped with a 60-horsepower motor and air compressor, with a Champion jaw crusher that makes 5-inch stone, and an American pulverizer for making sand. The sand is used for silica brick for electric furnaces and is shipped to Downington and elsewhere on the Pennsylvania Railroad, along whose tracks both crusher and quarry are located.

Analyses of the Chickies quartzite at Chickies station

	1	2
SiO_2	97.71	97.51
Al_2O_3	1.39	.99
Fe_2O_3	1.25	1.08
MgO	.13	
CaO	.18	.11
	100.66	99.69

1. Pirsson, L. V., Rocks and rock minerals, 1st ed., p. 367, 1908.
2. Pennsylvania Topog. and Geol. Survey Bull. M-3, p. 34, 1924.

Physical tests show that the fusion point for coarse material is 1,753° C., and for 150 mesh is 1,737° C.

A small opening for building sand (No. 24) a quarter of a mile north of Springet post office belongs to Bertha Buntin. The rock is crumbly *Scolithus*-bearing Chickies quartzite and is prepared for market by crushing and screening.

A small pit (No. 41) half a mile west of Marietta, near the Pennsylvania Railroad, is operated intermittently by the Marietta Sand Co. for molding sand. A layer about 3 feet thick lies on coarser sharp sand, and the deposit is apparently river alluvium.

CLAY

Origin.—Clay is a residue which remains after the decomposition or solution of some rocks and is composed of kaolinite with quartz and iron compounds as impurities. Kaolinite or kaolin is the chief product of feldspathic decay, hence from the decay of granite or pegmatite. Siliceous clay is residual from feldspathic sandstone, from shale, and from impure limestone as well as from igneous rocks such as granites and gabbros. Another source of supply is transported surface clay.

Brick clay.—The clays of the Middletown area used chiefly in the making of brick are residual clays, for the most part derived from the Gettysburg shale. Two brick plants are now in operation in the area, and one other was formerly operated.

The Hummelstown Brownstone Co., of Waltonville, operated a brick plant (No. 1) started in 1907 in connection with its building-stone quarry. The product was sand-lime brick in which three parts of sand from the Gettysburg shale was used with one part of burned unhydrated lime which was supplied by the Thomasville Lime & Stone Co., of Thomasville, York County. The argillaceous sandstone was crushed and dried in revolving cylinders, taken up in conveyor buckets after mixing with ground lime, made into brick in steam presses, and then steam dried. The plant averaged 62,000 bricks a day.

The Royalton Face Brick Co.'s plant (No. 3) is south of Swatara Creek and southeast of Middletown. The clay pit is east of the plant, along the bluff of the creek, and is in surface residual clay of the Gettysburg shale. The clay is about 20 feet thick and lies above harder rock, which is not used. A gasoline tractor hauls the clay from the clay pit to the grinding plant. After it is ground it is passed through an American bell pulverizer and is screened. It is moistened by steam under pressure before it is hand scrubbed by stiff steel brushes and finally conveyed to the mixer. From the mixer it passes to the press, where it is given a corduroy or velvet finish, and then by rollers to the wire-cutting machine. The bricks are loaded by hand from a moving belt to cars that carry them to the driers, which utilize waste heat from the kilns. Five beehive kilns of the down-draft type are in use. The product is shale brick, of many shades of light and dark red, and black manganese brick. The capacity of the plant is 42,000 bricks a day. It is near the Philadelphia division and the Columbia branch of the Pennsylvania Railroad.

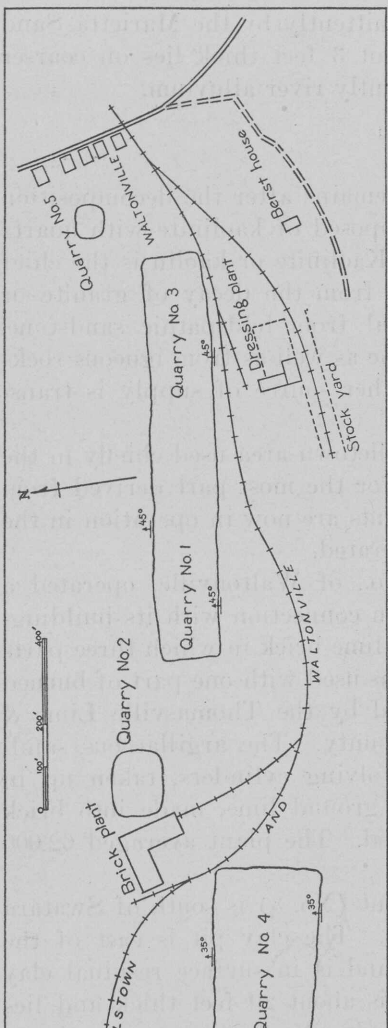


FIGURE 16.—Map of brownstone quarries at Waltonville, showing strike and dip of beds in quarries. Surveyed by M. N. Shaffner, Pennsylvania Geological Survey. Quarries Nos. 1 and 3, about 100 feet of thick-bedded even-grained red sandstone quarried, overlain by shaly sandstone. Quarry No. 4, about 150 feet of thick beds quarried, overlain by pebbly bed with 2-inch quartz pebbles and small flat pebbles of yellow calcareous shaly and blue limestone

The plant of the Manchester Shale Brick Co. (No. 18) is a mile north of Emigsville, between Highway 24 and the Pennsylvania Railroad. In 1928 it was owned by M. C. Colt, of Emigsville, but was closed down. The clay is derived from a 20-foot bed of red shale of the New Oxford formation. This shale dips 10°–20° NE. under arkosic sandstone. The present opening is 1,000 feet long and 100 feet wide. The clay was dug by an electric Bay City shovel and hauled in cars to the plant, which consists of four down-draft and two up-draft kilns. One of the down-draft kilns is a square Stewart kiln with chimneys in the ends. The product was wire-cut shale brick, both light and dark.

White clay.—White sandy sericite clay is quarried intermittently from the Cooper quarry (No. 22), half a mile south of Highmount, north of the road to Accomac. It is a decomposed fine even-grained sericitic quartzite or quartz schist in the upper part of the Chickies quartzite. The product is sent to Stoner Station to the plant of the Foundry Supply Co., owned by A. J.

Hershey, of York. It is mixed with some other substance for use as molding sand and is bagged and marketed under the name "Korite." Some of the crude white clay is shipped in bulk.

BUILDING STONE

The Hummelstown Brownstone Co., of Waltonville, operated a large quarry (No. 2) for building stone until 1928, but it is now inactive. (See pl. 14 and fig. 16.) The rock is a reddish-brown fine-grained sandstone which occurs in massive beds 10 feet thick between beds of pebbly sandstone that dip 25° N. The sandstone is part of the upper sandstones of the Gettysburg shale. The quarry was in operation for many years, and five pits had been opened, the most recent operations being conducted at the west end of No. 4 pit.

Section at west end of No. 4 pit

	Feet
Thick red sandstone (not quarried).	
Thick conglomerate	20
Quarry face:	
Massive red sandstone	20±
Well-bedded red sandstone	20±
Massive red sandstone with scattered shale pebbles	20±
Very massive even-bedded red sandstone	30±

The stone was dressed near the quarry, and blocks of all sizes and shapes and designs were prepared (see pl. 14, *B*) and were shipped by the Brownstone & Middletown Railroad, which connected the plant at Waltonville with the Lebanon Valley branch of the Philadelphia & Reading Railroad. Analyses of the stone are as follows:

Analyses of sandstone from Hummelstown Brownstone Co.'s quarry[a]

[Analyst, State College]

	Blue	Brown
SiO_2	90.34	88.96
Al_2O_3	4.35	4.74
Fe_2O_3	1.09	2.19
FeO	.74	
MgO	.17	.44
CaO	.95	.86
Na_2O	.19	.24
K_2O	1.30	1.31
H_2O	.61	.87
	99.74	99.61

[a] The stone industry in 1903, p. 159, U. S. Geol. Survey, 1904.

ORNAMENTAL STONE

Rhyolite has been locally quarried for road material from a small opening (No. 40) just north of Highmount, on the farm of Albert Fahringer, but the rock is hard and brittle and possesses no binding qualities. The purplish-red variety, because of its attractive coloring, is suitable for ornamental purposes when polished. The quarry was purchased by Henry Billet, of New York, a maker of monuments, who polished some blocks of the purplish rhyolite but did not use it to any extent because of its hardness and the irregular shapes into which the rock breaks in quarrying. If large masses can not be obtained there may be a moderate demand for smaller pieces in the manufacture of small articles such as paper weights, ornamental boxes, and jewelry.

IRON ORE

LIMONITE

Limonite, or brown hematite, is a chemical combination of iron oxide with water. It is in general brown with yellow and red varieties. It was precipitated, possibly as iron carbonate, from circulating underground water, especially at the contact of the Vintage dolomite and the underlying iron-bearing Antietam quartzite and also along faults that facilitated circulation of these waters. These deposits were worked for the most part in 1860 to 1880 and are described in the reports of the Second Geological Survey of Pennsylvania. At the present time none of the mines are active.

There is a line of ore pits along the contact of the Antietam quartzite and Vintage dolomite on the south side of the Hellam Hills. Beginning 2 miles west of Wrightsville these old banks are the Gohn, Benj, Strickler, Stoner, D. Rudy, Keller, Heistand, Blessing, Norse, and Miller [36] (Nos. 26–34). The ore pits northwest of the Hellam Hills, those of Smyser, Cottrel & Benson, and Small (Nos. 35–38), are located along Triassic faults. The ore was shipped by rail and canal boat to the furnaces at Marietta and Columbia. It was all arenaceous limonite, but the ore from Small's bank (No. 38) contained a large percentage of manganese and barite.

The ore from the Grubb bank [37] (No. 39) is different in character from the other deposits. It is a quartzite impregnated by iron oxide, one-third of which was reported to be magnetite and two-thirds red and brown hematite. It was called " rock ore " and was quarried from an open pit, dug in 1866 on the Codorus Furnace estate. (See pl. 15, *A*.) The ore was hauled down hill a mile to the Susquehanna River and floated down to St. Charles Furnace, above Columbia. It was mixed with ore from Chestnut Hill and Cornwall in smelting. Limonite ore was mined a mile northwest of Chickies at the Cooper bank (No. 43) and Duffy bank (No. 42) in

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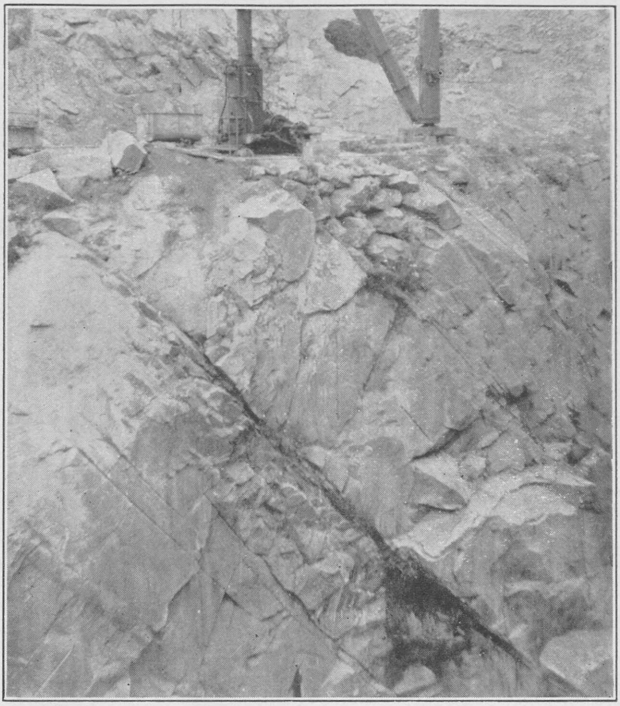
[36] Frazer, Persifor, jr., Report of progress in the district of York and Adams Counties: Pennsylvania Second Geol. Survey Rept. C, pp. 46–49, 1876.

[37] Idem, p. 64.

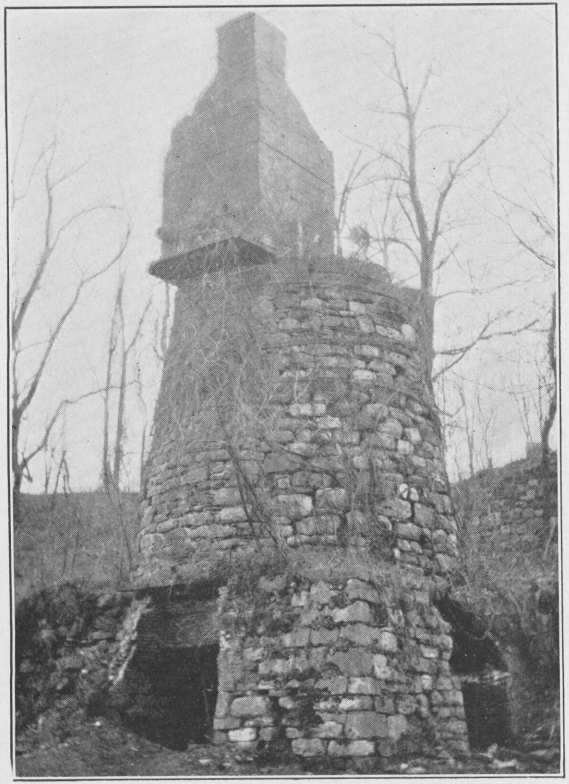


A. QUARRY IN THICK-BEDDED TRIASSIC RED SANDSTONE AT WALTONVILLE

Photograph by George H. Ashley.

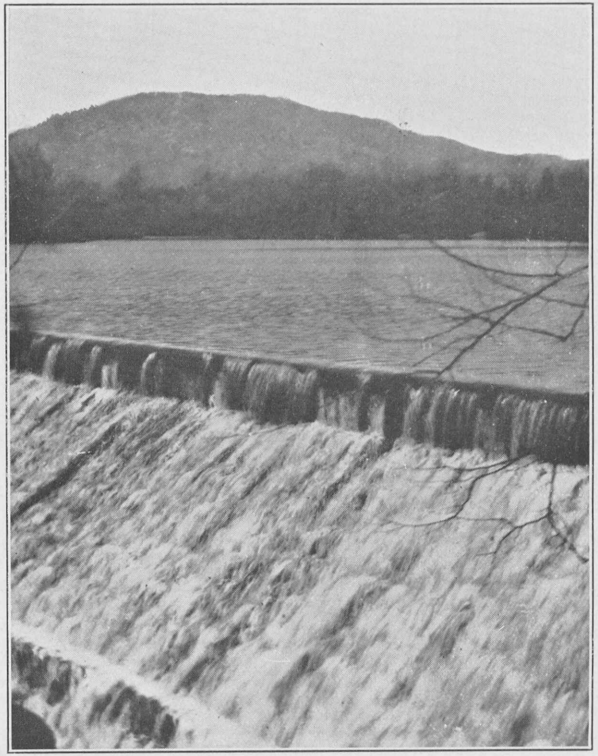
B. LARGE DIMENSION STONE FROM WALTONVILLE QUARRY

Photograph by George H. Ashley.



A. OLD CODORUS IRON FURNACE, NEAR MOUTH OF CODORUS CREEK

Built of Chickies quartzite.



B. ROUNDTOP AND MIDDLETOWN RESERVOIR, 7 MILES EAST OF MIDDLETOWN

Hill composed of Triassic diabase. In foreground water spilling over dam of reservoir.

the late seventies.[38] The ore occurs in the lower beds of the Vintage dolomite.

MAGNETITE, HEMATITE, AND ILMENITE

Hematite in small quantities occurs in places at the metamorphic contact of diabase and shale. It is especially conspicuous where a small dike leaves the bottom of the sheet of diabase 1 mile west of Yorkhaven, where the sandstone is largely altered to epidote and hematite. It probably does not occur in commercial quantities.

Ilmenite in small quantities occurs with the quartz that cements the brecciated pre-Cambrian rhyolite in Accomac Cove. It is of no economic value.

Magnetite has not yet been discovered in minable quantity in the area, but it is possible that deposits similar to those at the Cornwall mine, 6 miles northeast of the Middletown quadrangle, lie below the surface in the northern part of the quadrangle, where the intrusive stock of diabase is believed to penetrate the faulted limestone floor, as shown in Figure 7. Indications of mineralization are shown in prospect pits 1 mile north of Waltonville, in the Hummelstown quadrangle, where hematite, zinc blende, copper carbonate, and garnet occur in a crushed zone in the Triassic sandstone. Prospecting with the dip needle is therefore suggested along the contacts of the steeply crosscutting bodies south of Waltonville, at Bachmanville School, and farther east.

COAL

Coal does not occur in the bedrock that crops out in the Middletown quadrangle, but the silt in the bottom of the Susquehanna River and especially that of Swatara Creek carries fine coal which has been brought by the streams from the culm dumps and coal washeries of the coal fields to the north. The water of Swatara Creek has a black color from suspended coal. The silt is dredged from the river by small flat boats equipped with suitable machinery, chiefly in the vicinity of Columbia and Middletown, washed free from sand so far as possible, deposited on barges, and stored in great piles on the banks of the river. This material is burned largely as fuel in factories in Columbia, Wrightsville, Middletown, and Harrisburg and in the power plants along the river to augment the power obtained from dams. It is also shipped by rail. It is very fine and of low grade because of the admixture of sand and other impurities and is therefore used in a blower.

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[38] Frazer, Persifor, jr., The geology of Lancaster County: Pennsylvania Second Geol. Survey Rept. C3, pp. 223–224, 1880.

WATER RESOURCES

Precipitation.—The average annual precipitation in the Middletown quadrangle is about 41 inches. During the later part of spring and in summer it is considerably more than during the fall and winter. Summer storms are occasionally accompanied by hail, which does considerable damage to crops, especially tobacco, which is grown extensively in this region. The average date of the latest killing frost in spring is about April 10 and of the earliest in fall is about October 23. The average depth of total annual snowfall is about 40 inches. Snow ordinarily does not remain long on the ground. The average annual temperature for the region is about 52°. The summer mean is about 72° and the winter mean about 30°. The record maximum and minimum are about 100° and −13°.

Surface water.—The Susquehanna River, with a drainage area of about 26,000 square miles above Middletown, is the chief source for water in the Middletown quadrangle. It flows from Middletown diagonally across the southwestern part of the area to Columbia, a distance of about 20 miles. Its width ranges from one-third of a mile at Chickies Rock to 1½ miles at Threemile Island. The flow ranges from about 2,200 second-feet to about 700,000 second-feet, with a mean of about 36,000 second-feet. The river is subject to occasional serious floods, which, when accompanied by ice, cause a large amount of damage. The other streams that are wholly or partly within the area are comparatively small and are all tributary to the Susquehanna. They include Swatara Creek, with a drainage area of 570 square miles, tributary from the east at Middletown, only 5 miles of which is in the quadrangle; Conewago Creek, tributary from the east at the lower end of Threemile Island, drainage area 52 square miles, nearly all within the quadrangle; Conewago Creek, tributary from the west at Yorkhaven, drainage area 511 square miles, only 5 miles in the quadrangle; Conoy Creek, drainage area 19 square miles, tributary from the east a short distance below Bainbridge; Codorus Creek, drainage area 268 square miles, tributary from the west at the Pennsylvania Railroad bridge, only 5 or 6 miles within the quadrangle; Chickies Creek, tributary from the east at Chickies Rock, about 2 miles above Columbia, drainage area 127 square miles, part of it outside of the quadrangle.

Records of the flow of the Susquehanna River at Harrisburg have been collected since 1891, Little Swatara Creek near Pine Grove since 1919, Swatara Creek at Harpers since 1918, South Branch of Codorus Creek near York since 1925, and Codorus Creek at York from 1915 to 1923 and since 1926. The records of flow at these gaging stations, all of which are outside of the quadrangle, may be obtained from the Water and Power Resources Board, Harrisburg, Pa.

Municipal water supplies.—The communities on or near the Susquehanna River have available an unfailing source of water supply but one which should not be used for drinking without being properly treated. The other towns can obtain water supplies from the numerous streams that drain this region, as the average annual precipitation of 41 inches, with an average run-off of between 20 and 30 inches, provides sufficient flow in surface streams. Storage reservoirs should be used to provide water during the periods of low stream flow. Before constructing any large and important municipal waterworks information in regard to run-off should be obtained from the Water and Power Resources Board at Harrisburg.

The following descriptions of the municipal water supplies of the towns in the Middletown quadrangle are based on a State report[39] which describes conditions in 1914; they were brought up to date in 1930 by correspondence and field inspection.

Middletown, the largest town that is wholly within the area, has a population of 6,085 and is served with water by the Paxtang Consolidated Water Co., which controls the charter of the Middletown & Swatara Consolidated Water Co. and serves Royalton also. The water supply is collected in an impounding reservoir on Iron Run, a tributary of Swatara Creek (see pl. 15, *B*), just southwest of Roundtop. The raw water is carried in a 12-inch main to Royalton and across Swatara Creek to Middletown, where it is filtered and pumped to a 191,000-gallon standpipe. Additional water is obtained from the head of the canal along Swatara Creek, where a hydraulic pumping plant is installed in an old mill. A near-by gristmill, which also uses the water power for its operations, was built in 1745 and rebuilt in 1874 and is still in use. The old cornerstone, on which is carved a verse of Scripture in German and the date 1745, is preserved in the present building. For fire emergency the pumps can take water directly from Swatara Creek. The Iron Run supply is soft, but that of Swatara Creek is medium hard. Royalton uses raw water from Swatara Creek, the Pennsylvania Railroad being the chief consumer.

Elizabethtown obtains its water supply from a tributary of Conoy Creek northwest of the borough. It is furnished by the Elizabethtown Water Co. The water comes from five springs and one flowing well and after passing into a collecting basin is pumped directly into the mains. It supplies a population of about 3,940 persons, the Pennsylvania Railroad for locomotive use, and the industries of the borough. The Masonic Home, southwest of the borough, has a private supply from three springs.

[39] Pennsylvania Water-Supply Comm., Water-resources inventory, pt. 6, Water supply, 1914.

The Rheems Water Co. supplies the town of Rheems from a well 360 feet deep drilled on a hilltop 1 mile west of the town. A Meyers deep-well pump forces water to a 50,000-gallon reservoir, and a windmill pumps water from another well near by. Water is distributed by gravity to the town, the Pennsylvania Railroad, and industrial plants.

Florin, a village of about 1,200 inhabitants, is supplied with water by the Florin Water Co., owned by Eli Nissley. Water is taken from two wells drilled in the Cocalico shale on the hill north of the village, is pumped into an adjoining 160,000-gallon reservoir, and carried by gravity to the town. It is medium hard.

Mount Joy, which is partly in the Lancaster quadrangle, takes its water from Little Chickies Creek half a mile north of the borough line. The water plant was built in 1874, and the pumps are operated by water power from the creek, supplemented by a 50-horsepower gasoline pump. The reservoir is a quarter of a mile west of the creek. The water company supplies a population of 2,716 persons with an average of 500,000 gallons daily, distributed by gravity to the mains. The water is soft.

Marietta is supplied by the Marietta Gravity Water Co., whose plant was built in 1894. The town is in a limestone valley, and in order to obtain soft water, reservoirs were built in the quartzite hills of York County, south of the Susquehanna. One reservoir 40 feet square and with a capacity of 900,000 gallons, is built at 430 feet above sea level on Dugan Run, half a mile south of the Susquehanna. It derives its water partly from springs. Another reservoir, on Wildcat Run, is 500 feet above sea level, at the head of the falls over which the run descends to the river in a narrow gorge. This reservoir has a capacity of 1,400,000 gallons. The water is piped to the river and under it to the town, a distance of 2 miles. About 2,000 persons are supplied, and the average daily consumption is about 90,000 gallons.

The village of Rowenna, with a population of about 100 persons, is served by the Rowenna Water Co., incorporated in 1893. Water is pumped from an artesian well by windmill or auxiliary gasoline pump to a 23,500-gallon reservoir. The water is medium hard and is used only for drinking, water for other purposes being taken from cisterns.

Columbia, which lies partly in the Lancaster quadrangle, takes its water from the Susquehanna River. The local water company, incorporated in 1823, has 16-inch intake pipes in the river northwest of the city. The water after being pumped into settling tanks is filtered and pumped into a covered reservoir three-quarters of a mile north of the borough. The average daily consumption was about 726,000 gallons in 1914. In addition the Pennsylvania Railroad pumps 125,000 gallons daily from the Susquehanna River at Columbia for use of its roundhouse and shops.

Wrightsville, which is served by the Wrightsville Water Co., takes its water from Kreutz Creek and from a tributary of Kreutz Creek fed by springs a mile southeast of Strickler station, where there is a concrete reservoir. Water is pumped by water power from an intake in the race of an old mill in the southeast corner of the borough, about 600 feet from the river. The water is pumped into settling basins and filtered through a mechanical filter. The daily consumption is about 25,000 gallons, some of which is used for industrial purposes.

The Hellam Water Co. supplies soft water for Hellam borough, which has a population of about 600. Springs at the head of a valley 2 miles north of Hellam feed a receiving reservoir having a capacity of 350,000 gallons, 184 feet above the main street of the borough, or 585 feet above sea level, which is about the height of the springs. About 80 per cent of the consumption is domestic.

Emigsville, whose population is a little smaller than that of Hellam, receives its water from a private system owned by E. K. Emig. Six springs on the Emig farm, 1½ miles from the village, are connected with a 13,000-gallon reservoir in the village. There is also a dug well and pumping station at the Acme wagon works, which is held for emergencies. The daily consumption is about 9,000 gallons.

Water power.—The Susquehanna is one of the most important water-power streams in the eastern part of the United States, and from its headwaters in Broome County, N. Y., to Havre de Grace, Md., where it enters Chesapeake Bay, it flows through a busy industrial district. The power available 50 per cent of the time in the 20-mile stretch of the river within the Middletown quadrangle is about 90,000 horsepower.

The potential power of the other streams in the area is relatively very small primarily because of their small drainage areas and because only a few miles of the lower parts of the larger ones lies within the boundaries of the quadrangle. The streams wholly within the area are too small to be of value for power.

The only water-power development on the Susquehanna in the quadrangle is the plant of the Metropolitan Edison Co. at Yorkhaven. The water in the river is diverted to the head gates of the power plant on the west bank by a low dam extending diagonally across the west channel of the river to Threemile Island and across the east channel to the east bank of the river about 1 mile above Falmouth. The capacity of the installed water wheels is about 20,000 horsepower, operated under a head of about 22 feet.

A large water-power plant, begun in 1929, was completed in 1931 at Safe Harbor, in the McCalls Ferry quadrangle, about 11 miles below Columbia. The dam is 92 feet high and, including the power house, is over a mile long. Backwater from the dam extends to Columbia. The initial installation is 231,000 horsepower, with an ultimate capacity of 539,000 horsepower. The average head on the wheels is about 55 feet. Two great hydroelectric systems lie below Safe Harbor, the older one at Holtwood, Pa., and the newer one at Conowingo, Md. With the completion of the plant at Safe Harbor the power resources of the Susquehanna River below Columbia will be completely developed. The ultimate capacity of these three plants will be about 1,250,000 horsepower, which is greater than that of any other hydroelectric development in the United States.

The Safe Harbor Water Power Corporation connects with the widespread system of the Holtwood Dam, reaching into Baltimore, Lancaster, York, and Coatesville, and will supply power to the Pennsylvania Railroad when its lines from New York to Washington are electrified.

There were at one time numerous small gristmills operated by water power on Swatara, Conewago, Codorus, and Chickies Creeks. Some of them are still in operation, but they are not much used at present, as the improvements in transportation and manufacturing have made it possible to purchase flour and feed more economically from other sources. Some of these small water-power plants are used for pumping municipal water supplies.

At Aberdeen, where Conewago Creek cuts through the Deodate body of diabase, the stream has considerable fall and the power is utilized by a large mill. The Myers mill, 1 mile southeast of Emigsville, is an old gristmill on Codorus Creek which is still in operation. A mile farther upstream, west of Pleasureville, a dam furnishes power to the more modern Codorus mill. The water power in the gorge near the mouth of the creek, which was formerly utilized at the old Codorus Furnace and rolling mill, is no longer used.

Kreutz Creek, which heads in the hills south of the quadrangle and flows along the Wrightsville Valley to the river, has several small mills along its course. The Sprenkles mill, near Strickler Station, operates when there is sufficient water in the stream. The Wrightsville Power & Light Co.'s power plant in the creek at Wrightsville is now idle.

Ground water.—The ground-water conditions in southeastern Pennsylvania were studied in 1925 by G. M. Hall, and the following brief summary of the water-bearing properties of the rocks in the Middletown quadrangle is taken from data collected by him in this quadrangle and adjoining regions.

The Chickies quartzite, Harpers phyllite, and Antietam quartzite should yield small or moderate supplies of soft water to drilled wells. The water in these rocks occurs mainly in joints or fractures, and the success of a well drilled into them therefore depends on encountering one of these fractures. Small to moderate supplies of water can probably be obtained from the Cocalico shale. The water in this rock occurs in small fractures and along bedding planes and is fairly soft.

The water-bearing properties of the Cambrian and Ordovician limestones and dolomites differ greatly from place to place. These rocks are dense and impervious; but because of their soluble nature, solution channels have been formed along joint planes and other fractures. The number, size, and spacing of these openings are very irregular, and beyond a moderate depth the openings decrease in size and number with depth. It is therefore not wise to drill deeper if water is not encountered in the first few hundred feet. The records of more than 300 wells in southeastern Pennsylvania that end in limestone, dolomite, or marble show that most of them derive their water from the first 200 or 300 feet. The water in these calcareous rocks contains dissolved carbonates and is much harder than that in the quartzite or shale.

The sandstones and conglomerates of the Newark group can usually be relied upon to yield moderate to large supplies of water. However, some of these rocks are thoroughly cemented and contain few joints and will yield only small quantities of water. The argillaceous shales of the Newark group will in general yield only a little water, although where they are closely jointed or sandy they may yield rather large supplies.

Fresh diabase is a dense rock and will generally yield very little water. Weathered diabase near the surface is more porous and will usually yield small supplies. The most favorable place for encountering water in diabase is at the bottom of the weathered zone. Deeper drilling into the fresh diabase is not likely to encounter water.

The terrace deposits of silt, sand, and gravel along the Susquehanna River are thin and of small areal extent and are therefore of little importance as producers of water.

Springs.—No noted springs or mineral springs are developed commercially in the area. Springs from Cambrian sandstones are sought as water supplies for towns and villages, because such water is generally soft and free from excessive lime and iron. Many of the springs in these hard quartzitic rocks issue from faults. A large spring flows from the Chickies fault just north of Chickies Rock. It was a source of supply for the old Chickies Furnace settlement and is still well protected by high stone walls and a cement walk and is extensively used locally. Several fine springs near the Chickies fault at the river's edge and on the steep hill slope above, west of Accomac, are utilized by the summer colony that occupies the cottages along this picturesque part of the river. Other springs in the quartzite hills are used by farmers. Two of these lie on the upland just east of the mouth of Codorus Creek. Dugan and Wildcat Runs, on the north slope of the Hellam Hills, which are fed by many small springs from the Chickies quartzite, are ponded by dams, and the water is piped under the Susquehanna River to Marietta for the town supply. Spring water from the quartzites in the Pisgah Hills in the southern part of the quadrangle at the head of a tributary of Kreutz Creek, is collected in a reservoir and piped to Wrightsville for the town supply.

A large spring issues near the Highmount fault on the south side of the Hellam Hills in the valley of the North Branch of Kreutz Creek and is extensively used by the community in the cove at this place. Another spring comes out at the east-west fault near the head of this branch of Kreutz Creek. Many other small springs flow from these rocks throughout the Hellam Hills and adjacent quartzite hills and form clear brooks that supply the farms in the ravines and the foothills with an abundance of pure soft water the year round. A spring issues from the top of the Chickies quartzite near its contact with the Harpers phyllite, 1 mile south of Mount Wolf.

A large spring issues at a fault in the limestone just south of Hellam, but the spring 1 mile west of Hellam is apparently not at a fault but at the base of the Kinzers formation. A large spring flows from the limestone near the cross fault south of the Myers mill, and another to the south, near the contact with Antietam sandstone, is probably also at a fault. A good spring issues from the Vintage-Antietam contact in the axis of the Emigsville syncline, 2 miles east of Emigsville. Another large spring comes out at the contact of these two formations 1 mile east of Rowenna.

Springs also occur in the limestone at places not definitely connected with fault fractures or with sandy beds or shale. Such a spring lies 1 mile east of Maytown, and there are two others along Donegal Creek 1 and 1½ miles southwest of Florin. The most noted spring in the region is one of these limestone springs at the historic Irish settlement around Donegal Spring Church, 2½ miles southwest of Florin.

Springs are not numerous in the Triassic rocks of the region, and many of the streams and wells in this part of the area run nearly dry during prolonged droughts. Several good springs issue at the contact of the red sandstone and the diabase in the Yorkhaven sheet. A large spring of this sort lies just east of Colebrook, and another near the head of Little Conewago Creek, 1 mile north of Upper Lawn. A spring issues from the fault contact of the Triassic and Ordovician limestone 1 mile west of Waltonville.

INDEX

QUARRIES AND PITS

STONE (LIMESTONE)

7. Hipple quarry, Penn Limestone & Cement Co.
9. H. K. Landis Stone-meal Co. (also fertilizer)
10. Strickler & Hinkle (also cement blocks)
14. J. E. Baker, Northwest Billmeyer quarry (also roasted dolomite)
16. J. E. Baker, Mount Wolf quarry, Saginaw (also lime and burned dolomite)
21. Susquehanna Stone Co.

STONE (BAKED SHALE)

4. E. M. Keener
5. Heisey Brothers

LIME

13. J. E. Baker, Princess quarry, Billmeyer (also stone)

LIME (INACTIVE)

8. H. L. Heisey
11. Sam Meckley
12. Rowenna
15. Kennedy
20. Stacey-Wilton Co.
23. Wrightsville Stone & Lime Co.
25. Emigsville Limestone Co.
44. Haldeman (also flux)
45. Chickies (also flux)
46. Beard Lime Co.

BUILDING STONE

2. Hummelstown Brownstone Co.

ORNAMENTAL STONE (RHYOLITE)

40. Henry Billet

SAND

6. Heisey Brothers
17. Fred Doll
19. Harry & Charles Shenk
24. Bertha Buntin
41. Marietta Sand Co.
47. ?

BRICK CLAY

1. Hummelstown Brownstone Co.
3. Royalton Face Brick Co.
18. Manchester Shale Brick Co.

WHITE CLAY

22. Cooper quarry

IRON ORE

26. Gohn bank
27. Benj. Strickler
28. Stoner
29. Dr. Rudy
30. Keller
31. Heistand
32. Blessing
33. Norse
34. Miller
35. Smyser
36. Cottrel
37. Benson
38. Small
39. Grubb bank
42. Duffys
43. Cooper

EXPLANATION

SEDIMENTARY ROCKS

Stream deposits of Susquehanna River — Pleistocene and Recent — QUATERNARY

Altitude: Qlt³ 340'–400'; Qlt² 300'–340'; Qlt¹ 240'–300'

Lower terrace and recent flood-plain deposits

(Sand, gravel, and scattered large boulders, chiefly of quartzite, on nearly continuous terraces bordering the river; Qlt¹, Talbot (?), 0 to 30 feet above the river; Qlt², Wicomico (?), 60 to 70 feet above the river; Qlt³, Sunderland (?) 80 to 100 feet above the river)

Eocene (?) to Pliocene (?) — TERTIARY

Tht³ 750'; Tht² 620'; Tht¹ 500'–520'

Higher terrace deposits

(Small remnants of gravel and sand; Tht¹, Bryn Mawr (?), 270 feet above the river on the Harrisburg (?) peneplain; Tht², 400 feet above the river; Tht³, 500 feet above the river)

UNCONFORMITY

Upper Triassic (Newark group) — TRIASSIC

Ꞧgc, Ꞧg

Gettysburg shale

(Chiefly soft red sandstone and shale and crumbly conglomerate; baked to hard sandstone and purplish-black porcelanite adjacent to intrusive diabase, shown by red ruling; thick beds of coarse conglomerate, Ꞧgc, near western edge of the Triassic)

Ꞧno, Ꞧqc, Ꞧlc

New Oxford formation

(Red to purplish shale and sandstone interbedded with light-gray to yellow arkosic sandstone and crumbly conglomerate; baked to hard purplish-black porcelanite and light-gray sandstone adjacent to intrusive diabase, shown by red ruling; beds of quartzose conglomerate, Ꞧqc, and limestone conglomerate, Ꞧlc, locally at base)

UNCONFORMITY

Lower (?), Middle, and Upper (?) Ordovician — ORDOVICIAN

Oc

Cocalico shale

(North of Hellam Hills-Chickies Ridge uplift; dark-gray to bluish-black shale; Trenton and probably younger)

UNCONFORMITY

Ocs, Ocss

Conestoga limestone

(South of Hellam Hills-Chickies Ridge uplift; thin-bedded blue limestone with argillaceous partings, closely folded and veined with calcite, and coarse limestone conglomerate; lower part possibly of Chazy or Black River age; light and dark gray banded earthy sandstone and dark-blue shale, Ocss, at base)

MARKED UNCONFORMITY

(Overlaps down to Vintage dolomite)

Lower Ordovician

Ob

Beekmantown limestone

(Pure blue limestone, laminated light-blue magnesian limestone, and lenticular gray dolomite veined by calcite and quartz; contains some black chert and coarse white marble; sparsely fossiliferous)

Upper Cambrian — CAMBRIAN

Ꞓcg

Conococheague limestone*

(Light-gray limestone banded with siliceous and argillaceous layers, dark and light gray dolomite, and cream-colored to white fine-grained marble with impure laminations; contains reefs of Cryptozoa in pure limestone; weathers to fine light-yellow sandy soil with shale fragments)

Ꞓl

Ledger dolomite

(Pure granular light-gray dolomite mottled with dark gray, extensively quarried for dolomite and crushed stone; weathers to deep-red granular clay soil)

Ꞓkl, Ꞓk

Kinzers formation

(Not present north of Hellam Hills uplift; lower part dark fissile to blue hackly shale; upper part blue limestone banded with dark impure layers and white marble spotted with irregular dolomite lenses, Ꞓkl, mapped south of Emigsville)

Lower Cambrian

Ꞓv

Vintage dolomite

(Glistening dark-blue dolomite with irregular knotty argillaceous impurities and fine earthy white marble at base; weathers to deep-red clay soil)

Ꞓa

Antietam quartzite

(Light-gray to rusty-brown finely banded quartzite, fine quartz schist, and at top hard blocky granular ferruginous, calcareous quartzite with fossiliferous layers)

Ꞓh

Harpers phyllite

(Grayish green phyllite and dark and white banded sericitic slate)

NORTH OF VALLEY — Ꞓcq, Ꞓc, Ꞓhs, Ꞓch

Chickies quartzite

Massive beds of hard white scolithus-bearing quartzite and quartz schist; thin-bedded sericitic granular quartzite with thin beds of dark slate at top; heavy quartzite, Ꞓcq, mapped locally to show structure; Hellam conglomerate member, Ꞓch, at base; dark slate beds in Hellam, Ꞓhs, locally mapped)

SOUTH OF VALLEY — Ꞓq, Ꞓcs, Ꞓch

Chickies slate

(Chiefly dark sericitic slate with many thin quartzite layers and some thicker quartzite beds, Ꞓq; Hellam conglomerate member, Ꞓch, at base)

*Part of Ozarkian system of E. O. Ulrich

METAMORPHIC ROCKS — PRE-CAMBRIAN (ALGONKIAN ?)

mb

Metabasalt

(Altered basalt lava flows)

vs

Volcanic slate

(Blue and dark-purple sericitic slate, in part amygdaloidal)

ar, arb

Aporhyolite

(Altered rhyolitic lava flows; arb, zone of brecciated pink rhyolite cemented by clear blue quartz containing some ilmenite)

IGNEOUS ROCKS — Late Upper Triassic — TRIASSIC

Ꞧd

Diabase

(Large sills and crosscutting bodies of coarse-grained dark crystalline rock and narrow dikes and thin sheets of fine-grained to aphanitic diabase called "ironstone")

U / D — Normal fault *(U, up side; D, down side)*

T — Thrust fault *(T, overthrust side)*

45° — Strike and dip of rocks

80° — Strike and dip of overturned beds

Strike of vertical beds

Horizontal beds

Active quarry

Abandoned iron-ore pit or quarry

PRODUCT

B, brick
Bs, building stone
Cb, cement block
F, flux
Fz, fertilizer
I, iron
L, limestone
S, stone
Os, ornamental stone
Sd, sand
D, dolomite
Wc, white clay

ECONOMIC NOTE

Gettysburg shale
(Thick red sandstone beds quarried for building stone; red shale beds suitable for brick and tile manufacture)

New Oxford formation
(Disintegrated sandy beds dug for building sand and gravel)

Cocalico shale
(Suitable for brick clay)

Conestoga limestone
(Extensively quarried for broken stone, road material, concrete, and building stone; formerly burned for lime; residual clay used for brick and tile)

Beekmantown limestone
(Extensively quarried for building stone and broken stone and formerly burned for field lime)

Conococheague limestone
(Quarried for broken stone and road material)

Ledger dolomite
(Extensively quarried for dead-burned dolomite for furnace lining and for flux and broken stone)

Kinzers formation
(Limestone beds quarried in places for foundation stone and broken stone)

Vintage dolomite
(Quarried for broken stone and burned for lime)

Antietam quartzite
(Quarried for foundation stone, road material, and ballast; source of iron-ore deposits)

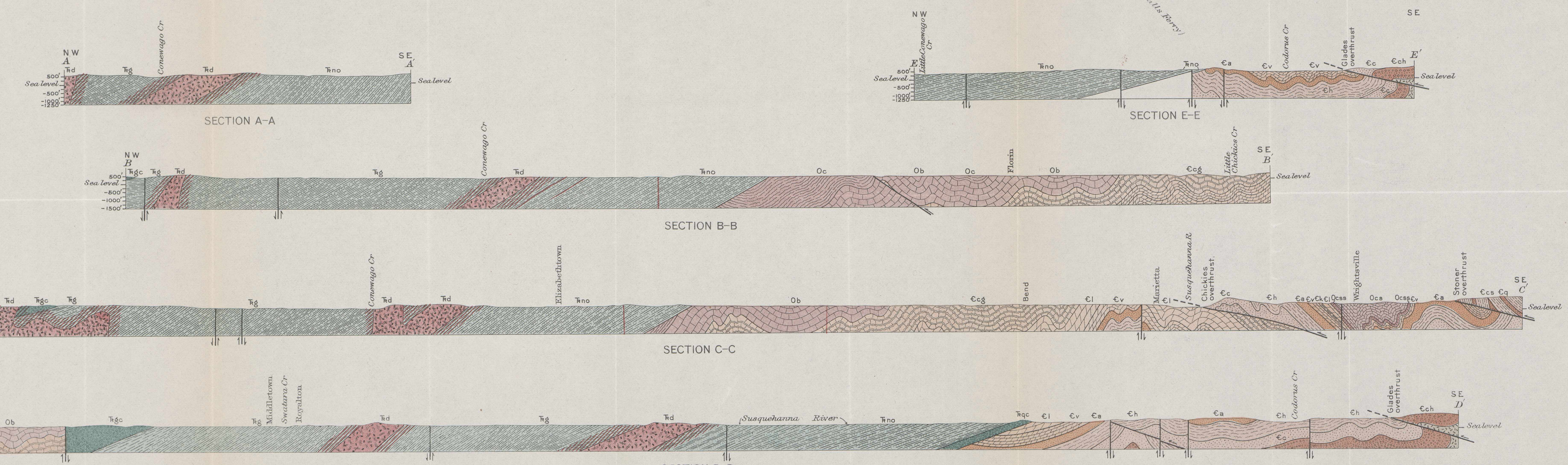
Harpers phyllite
(Used locally for road material)

Chickies quartzite
(Quarried for building sand, foundation stone, and quartz sand; residual white sericitic clay used in molding compound)

Aporhyolite
(Quarried for ornamental stone and building stone)

Diabase
(Quarried for road material, building stone, and retaining walls)

Iron ore
(Formerly extensively mined at contact of Antietam quartzite and Vintage dolomite and at fault contacts)



SECTION D–D

GEOLOGIC MAP AND SECTIONS OF THE MIDDLETOWN QUADRANGLE, PENNSYLVANIA

Base by U. S. Geological Survey, surveyed in cooperation with the State of Pennsylvania

TRUE NORTH / MAGNETIC NORTH — APPROXIMATE MEAN DECLINATION 1932.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

1932

Geology by George W. Stose and Anna I. Jonas
Surveyed in 1926–1929 in cooperation with the State of Pennsylvania