CORRELATION OF MARYLAND AND PENNSYLVANIA
PIEDMONT FORMATIONS*

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INTRODUCTION

The generalizations and conclusions presented in the present paper are based on the detailed work of the writer and his assistants on the Maryland Geological Survey, covering the territory from the Susquehanna river to longitude 76 degrees 50 minutes, with the exception of a small area in the immediate vicinity of Baltimore, and on the lines determined by the late Professor Williams, confirmed by a rather detailed reconnaissance by the author, on the territory west of this line to the area of the Frederick and West Washington sheets, where the work of Mr Keith, supplemented by reconnaissance work by the author, is used. The writer has also had access to the field notes, manuscript material, and microscopic sections of Professor Williams, which were prepared by him during his work on the United States Geological Survey. The conclusions reached from the information received from these various sources are, however, the work of the writer, who alone is responsible for them.

* Published by permission of the Maryland Geological Survey.

During the course of the work in the Maryland area, extending over a period of ten or twelve years, there have been frequent conferences with Miss Bascom, who has been engaged in investigations in the Piedmont area, and the knowledge of the results there gained have been generously placed at the disposal of the writer at all times. The conclusions reached, independently in the Pennsylvania and Maryland areas, are found to be in practical accord, and it is the purpose of the present paper to show the harmony of interpretation in these two areas and to discuss the southward continuation of the various formations and structures described by Doctor Bascom in the preceding paper.

FORMATIONS OF THE PIEDMONT

LIST OF THE FORMATIONS

In a paper previously published by the author* it was shown that there are within the Maryland area six well defined sedimentary formations and numerous rocks intruded in them. The sedimentary formations are as follows:

Ordovician?	{ Peachbottom slates. Cardiff quartz conglomerate Wissahickon mica-schist, including phyllite with intercolated lime- stone bands at the top.
Cambro-Ordovician (Shenandoah)?.	Cockeysville† marble.
Cambrian.....	Setters† quartzite.
Pre-Cambrian.....	Baltimore gneiss.

BALTIMORE GNEISS

The oldest formation in Maryland is the Baltimore gneiss, which occurs in several well defined areas in the eastern portion of the Piedmont between the Susquehanna and Potomac rivers. The easternmost of these Baltimore gneiss occurrences is within the area of Cecil county, east of the Susquehanna river, studied by Doctor Bascom, and extends from this point southwestward, widening to an area of 5 miles or more in breadth where it is overlain by Coastal Plain deposits. This formation is limited on either side by igneous rocks. An outlier a mile or less in width, extending for several miles southwestward from the Susquehanna river,

* The structure of the Piedmont plateau as shown in Maryland. *Amer. Jour. Sci.*, 4th ser., vol. xvii, 1904, pp. 141-159.

† The terms Cockeysville and Setters are old terms employed by Williams, which are here used pending the final decision on names by the Committee on Formation Names of the U. S. Geological Survey. It is not thought that they represent any different horizons from the Chickies quartzite and Chester Valley limestone of the Philadelphia area.

probably represents a detached portion of this larger mass lying a little to the south.

The second occurrence* of Baltimore gneiss is found in an anticlinal dome, 15 miles long and 5 miles broad, lying on either side of the North-

FIGURE 1.—Distribution of Formations in Maryland Piedmont and contiguous Areas.

ern Central railroad 10 miles south of the Mason and Dixon line and 20 miles north of Baltimore.

* Detailed maps of the region north of Baltimore accompany the following paper by the author and Mr Miller.

Three smaller areas occur in the vicinity of Baltimore. Two of them are portions of anticlinal domes which are either completely enclosed by overlying sediments or cut off by faults and igneous rocks, while the third, underlying the northwestern part of Baltimore city, is entirely surrounded by gabbro and other igneous masses and is overlain in great measure by the Coastal Plain deposits.

Between Baltimore and Washington, along the boundary line between Montgomery and Prince George's counties, occurs another area of Baltimore gneiss, which up to the present has not been fully investigated by the author.

The rocks in each of these areas consist of highly crystalline gneisses composed of quartz, feldspar, and mica, with accessory minerals, which are so distributed as to produce well marked, gray banded gneisses, the individual bands of which vary from a fraction of an inch upward, the average thickness, however, being quite thin. Some of these beds are highly quartzose, resembling a micaceous quartzite; others are rich in biotite or hornblende, producing dark schists, which in a hand specimen are indistinguishable from metamorphosed igneous masses. Within the area of Baltimore gneiss are numerous small bodies of metamorphosed granites and more basic igneous rocks, which have been intruded into the gneiss and subsequently metamorphosed until they are practically indistinguishable from it. The differences in character can now and then be recognized, but it has not been found possible to carry the mapping of these small igneous intrusions from one exposure to another, and frequently they are so small that they could not be represented on maps of the scale (1 : 62,500) employed.

SETTERS QUARTZITE

The Setters quartzite occurs usually as a narrow rim on the flanks of the areas of Baltimore gneiss, but is not continuous or always present. Thus in the easternmost areas of Baltimore gneiss previously described no Setters quartzite was recognized. It was found, however, skirting the anticlinal dome of Baltimore gneiss along northern Baltimore county, where it occurs as a single band on the eastern end of the dome and as a series of somewhat parallel ridges on the northwestern slope of the anticline, where the contact between the underlying gneiss and the quartzite is near the present surface of the country. On the southern slopes of the anticlinorium the quartzite seems to be lacking along the western half, but is found in varying thickness along the eastern part of the anticline.

The quartzite also occurs in the smaller anticline about a granite mass in the vicinity of Warren, just south of the previously described anticlinal dome.

Quartzite from the typical ridge originally described by Professor Williams occurs as a continuous belt about the small anticlinal dome lying 10 miles northwest of Baltimore between the Northern Central and Western Maryland railroads. The formation here is of rather uniform thickness and stands at a steep, sometimes overturned, angle on the flanks of the gneiss. Across the valley of lake Roland is a similar, though less well defined, anticlinal arch of more complicated structure, along the sides of which may be seen the Setters quartzite, extending from the Northern Central railroad on the west to the eastward until it is cut off by overlying formations or igneous rocks.

The Baltimore area of gneiss is included entirely within the gabbro, and no quartzite is to be noted along its borders.

On the western side of the Baltimore area, extending southward through Howard county, may be found occasional exposures of Setters quartzite between the gneiss and the marble. The work in this area has not been completed, but it seems quite probable that the quartzite will be found developed as a more or less continuous stratum lying between the Baltimore gneiss on the east and the overlying marble on the west, as it has already been recognized in this position at many points.

The quartzite is a fine-grained, somewhat saccharoidal, thin-bedded rock of white or cream color in its typical development along Setters ridge. At this point the beds are usually separated by thin films of muscovite or sericite in small sparkling flakes. On the surface between the individual beds are black tourmalines, which have been more or less disturbed, as shown by the stretching which they have undergone. The Setters quartzite as a formation is, however, somewhat more variable than was at first supposed from the study of the original locality on the south side of Greenspring valley. Locally the rock may become very vitreous and massive, resembling some of the Huronian quartzites of the Lake Superior region. At other times the rock becomes more argillaceous, with a development of garnets, staurolite, and other accessory minerals. The development of such minerals causes the quartzite formation to simulate in lithologic character the overlying Wissahickon mica-schist, and at first occasioned considerable difficulty. It is now known, however, that the more quartzose layers may be intimately interbedded with the more micaceous and garnetiferous ones toward the center of the formation, and that the upper portion of the formation when well developed may be highly micaceous and garnetiferous.* The develop-

* The presence of a somewhat sericitic quartzitic lower member and a more argillaceous overlying member is strikingly in accord with the characteristic Cambrian deposits of York county, Pennsylvania, and those of the Catoctin area described by Keith, as well as those of Balcony falls, Virginia, as described by Campbell. There is, however, more metamorphism with the development of metamorphic minerals in the rocks of the eastern Piedmont.

ment of this micaceous phase of the Setters formation is especially marked along the valley at Stringtown and in the northeastern extension of the limestone valley at Cockeysville. A third instance of this character is found in the small anticline at Warren, especially near the mouth of Royston branch. In all of these instances the micaceous member of the quartzite is seen to *underlie* the marble and to *overlie* or to be interbedded with the more quartzose phases of the Setters formation. Moreover, the structure at the various points is such that the occurrence of this garnet mica-schist can not be explained as a faulted-in portion of the Wissahickon mica-schist overlying the marble, as was first supposed by the writer.

COCKEYSVILLE MARBLE

The exposures of Cockeysville marble found in the Maryland Piedmont may be included within an ellipsoidal area with a major diameter of 40 miles extending northeast and southwest from Harford county on the east to Montgomery county on the south and a minor diameter of about 10 miles. The areal distribution suggests that there was in Maryland a local basin of deposition, but there are few, if any, facts known confirming this suggestion. The maximum development of the Cockeysville marble is found in the synclinorium* lying between the anticlines of Baltimore gneiss and quartzite about 10 miles north of Baltimore city. It is here found underlying the Wassahickon mica-schist and overlying the quartzite, the various formations recurring at the surface through numerous foldings, the contact between the marble and the adjacent formations lying very close to the present surface of the country. Southwest from this larger area of Cockeysville marble the formation may be traced in four exposures along well defined valleys to the vicinity of Clarksville, in Howard county, with but little or no interruption, the formation occurring as part of a monoclinal fold to the westward or as the eastern side of the large synclinorium which will be discussed later. The details regarding the southwestern exposure of the Cockeysville marble are not all worked out, and it seems quite probable, from the facts at hand, that there is a fault striking northwest and southeast and extending southeastward to a point near Laurel. The marble occurring in these areas is in the majority of instances rich in magnesium and should be called a dolomite. This is particularly true at the type locality, Cockeysville, but there are frequent changes in the amount of magnesium present, and one often finds magnesium-free or magnesium-poor rocks in proximity to the dolomitic varieties. The changes in composition are

*The distribution and structure of the Cockeysville marble as exposed in this synclinorium is discussed in detail in the succeeding paper by the author and his associate, Mr W. J. Miller.

sharp and generally easily recognized by the quarrymen, who are assisted by the fact that the dolomitic marble averages finer grained and richer in magnesium-mica than the better-burning, magnesium-poor rocks. Attempts have been made by acid tests in the field to recognize some stratigraphic distribution of the magnesium and calcium-rich rocks, but these have failed. On the contrary, it has been found that there are rapid sharp alternations of the two types in a way which strongly suggests that whatever dolomitization occurred must have taken place prior to emergence from the sea and probably contemporaneously with the formation of the deposit as has recently been described by Professor Branner as occurring on the coast of Brazil.

No fossils have been found in the marbles, and as they are highly crystalline it is very doubtful if any will be found. The deposit, however, underlies the Wissahickon schist in exactly the same way as the Chester Valley marbles underlie the typical Wissahickon schists, which have been traced continuously into the Maryland areas.

WISSAHICKON FORMATION

The Wissahickon formation in Maryland occurs as a broad band wrapping about the older Baltimore gneiss and limestone areas and occupying practically all the territory between the Blue Ridge and the Coastal Plain deposits except those portions consisting of the sedimentary rocks already described, the overlapping Triassic sandstones of Carroll, Frederick, and Montgomery counties and the igneous rocks. This wide belt of rocks may be roughly divided into the Wissahickon schists and the Wissahickon phyllites with included limestone lenses. The line of separation between these two divisions is not marked stratigraphically by any pronounced change in lithologic character, and it is not entirely clear that the division is a stratigraphic one, although it seems probable that the phyllites in all instances are of as high or higher horizons than the more crystalline Wissahickon schists. It has been clearly shown by recent field work that the more crystalline Wissahickon schists pass by gradations into the less crystalline phyllites and sericite schists. The more crystalline aspects of the Wissahickon formation lie in the eastern part of the Maryland Piedmont, where they are in association with the older, more crystalline sedimentaries and the large masses of intruded gabbros, granites, and other igneous rocks.

The areal distribution of the Wissahickon formation may be discussed in four parts. The area of Wissahickon schists lying east of the broad phyllite band, which extends southward from the Susquehanna river to southeastern Carroll county, represents the area of highest crystallinity

and closest similarity with the Wissahickon schists of the type locality near Philadelphia. The formation in this part of its development broadens from a narrow band at the Susquehanna river by increased folding about the anticlines of Baltimore gneiss and synclines of Cockeysville marble into a belt 10 to 15 miles broad as it crosses the Northern Central railroad. From this point it narrows somewhat to the southwestward, and the area is occupied in large part by the large mass of granite passing from Sykesville southwestward to Washington and extending thence many miles southward into Virginia.

North of the phyllite syncline occurs a corresponding mass of more crystalline Wissahickon schist. When, however, this is compared with the rocks on the southern limb of the synclinorium it is found that these rocks average slightly less crystalline and less metamorphosed than the corresponding rocks on the south. That they represent the same horizon seems to be well established by the areal distribution of the various masses, although it has been found impossible to carry the mapping of individual beds more than a few miles along the strike, and hence it has seemed inadvisable to attempt detailed cartographic representation. The Wissahickon schists on the west side of the syncline of phyllites passes southwesterly across the state, narrowing considerably in the southern portion of Carroll county and widening somewhat in passing southward to the Potomac river. The areal mapping of this region has been carried out in considerable detail by Mr Keith, of the United States Geological Survey, who has shown that the line of separation between the eastern and western portions of the Piedmont plateau, as laid down by Williams,* is in reality a sharply crenulate line, due to the folded structure of the area, which brings the contact between the phyllites and the more crystalline schists repeatedly to the surface.

The band of phyllite, forming a synclinal trough extending from the Susquehanna southward, enters the state from York county, Pennsylvania, continues as a belt, varying from 5 miles in thickness at the Susquehanna to about a mile at Whitehall, on the Northern Central railroad, whence it gradually widens southward to an average breadth of 3 miles in the southern part of Carroll county. The areal distribution indicates that we have a synclinal trough of considerable extent and well defined character, which is buckled at its center, and plunges northeastward and southwestward, reaching its maximum depth in the vicinity of Delta, Pennsylvania, where the Cardiff quartzite-conglomerate and Peachbottom slates are found folded within it. The southern termination of this phyllite belt has not been mapped in detail, and the limits here given

* Bull. Geol. Soc. Am., vol. 2, 1892.

are based on reconnaissance work on the part of Doctor Williams and the writer. Throughout its entire extent no limestone has been found up to the present time. It is, however, quite possible that small masses of this material have been overlooked, as the area traversed is a portion of the less dissected part of the Piedmont plateau, where the easy disintegration of the less resistant phyllites offers few exposures. The areal mapping, however, is easily carried on from a study of the fragments, which occur plentifully in the soil.

The rocks constituting the phyllite portion of the Wissahickon formation are essentially sericitic, chloritic, and occasionally talcose schists, which clearly show their sedimentary origin, and have been less metamorphosed than the Wissahickon schists already described. Two views are held regarding their relations to the contiguous formation. They may be regarded as an infolded younger series, as held by the late Professor Williams, or they may represent a less metamorphosed portion of the Wissahickon formation. It seems probable that there is truth in both views, and during recent years the impression has developed that they represent the upper portion of the Wissahickon formation, which has been less metamorphosed, but that they are not separated by any great interval from the more crystalline Wissahickon schists which border them on either side, and from which they cannot be separated by any sharp line. When crossing the boundary between the two formations one may recognize within comparatively short distances that a boundary has been passed, but up to the present no contacts between the two portions of the Wissahickon formation have been found. The interpretation of the phyllites here discussed does not necessarily or even probably apply to the more extensively developed phyllites lying a little farther west, though some of the latter may be the equivalent of the more eastern phyllite.

The western phyllitic rocks composing the area between Parrs ridge on the east and the sedimentaries lying at the base of Catoctin mountain occupy a broad belt which enters the state of Maryland from Pennsylvania and crosses the state into Virginia. Detailed work on this territory has not yet been completed, but the facts at hand would seem to indicate that they rest on the Shenandoah limestone of the Frederick valley, and are in turn overlain by the Triassic sandstones and shales. Passing westward from the more crystalline rocks east of Westminster, there appears to be a constantly decreasing amount of recrystallization and metamorphism until along their western margin they present characters similar to those of ordinary shales. Within this broad belt of phyllites occur numerous narrow valleys of limestone or crystalline marble and lenticular areas of chloritic and sericitic schists, which are

manifestly the metamorphosed representatives of surface volcanoes. The western limits of the slightly altered phyllitic rocks and their relation to the sedimentary rocks of known age at the base of Catoctin mountain have thus been described by Professor Williams: *

"If we follow the succession of strata eastward from Catoctin mountain, which bounds the Piedmont plateau on the west, we find above the hard Cambrian sandstone a little limestone, which, however, is immediately buried beneath the overlap of red sandstone. This blue limestone, whose fossils show it to be of lowest Silurian (Trenton) age, soon, however, emerges from beneath the overlying and unconformable Triassic (Newark) sandstones as a series of considerably folded beds, which are succeeded on the east and apparently overlain by carbonaceous and hardly altered shales. These are like those which occupy a similar position above the same limestone farther westward [Martinsburg shales]. Still beyond there follow with the easterly dip the thick beds of sandstone which compose Sugarloaf mountain. . . . The Sugarloaf sandstone passes on its eastern side upward by a gradual transition to shaly layers into sandy slates, and these again into the succession of sericite and chloritic schists, which compose the mass of the semi-crystalline area."

CARDIFF QUARTZITE

The quartzite and quartzose conglomerate which occur in the northeast part of Harford county form a narrow band apparently resting on the phyllite and underlying the Peachbottom slate, wrapping around the latter and extending beyond its southwestern limits to the valley of Broad creek. The formation is of small thickness and of slight extent.

PEACHBOTTOM SLATES

The Peachbottom slates extend as a narrow strip within the limits of the Cardiff quartzite and pass beyond it across the Susquehanna river into Lancaster county, Pennsylvania. The formation is composed entirely of characteristic blue-black slates, similar to the material put on the market, and the homogeneity of the formation is now so complete that it is impossible to perceive within it any succession of sedimentary beds. It is usually considered, however, that the central portion of the ridge differs somewhat from the sides, and that the formation represents the uppermost member in a tightly pinched syncline.

The age of these Peachbottom slates has been somewhat questionably determined on doubtful fossil evidence to belong to the Hudson River horizon of the Ordovician. If this correlation is correct, we have an upper limit fixed for the age of the deposits of the eastern Piedmont in Maryland, and an apparent confirmation of the position assumed that

* Maryland, Its Resources, Industries, and Institutions. Baltimore, 1893, p. 66.

the Wissahickon is itself of Ordovician age, since there is no well defined and extensive line of separation between the Wissahickon and these locally developed slates.

AGE OF THE FORMATIONS

Within the Maryland Piedmont, so far as studied in detail, there are no means of locating accurately the position in the stratigraphic column of the four formations—Baltimore gneiss, Setters quartzite, Cockeysville marble, and Wissahickon schists and shales—but on either end of a continuous extension of these formations we have a sequence into sedimentary rocks of known horizon. On the east Doctor Bascom has shown that the Baltimore gneiss is pre-Cambrian, the quartzite Cambrian, the limestone Cambro-Ordovician, and the Wissahickon Ordovician. On the west the phyllites are apparently in the same relation to the known Cambrian and Cambro-Silurian deposits, although in this area the geological mapping has not been conducted in detail on account of the lack of satisfactory topographic maps. The conclusion from the facts at hand would therefore seem to warrant the correlation shown on page 340.

Opposed to this conclusion is the fact that directly on the strike of the Wissahickon schist are a series of more quartzose and more compact metamorphosed sediments, which have been regarded by Mr Keith, in his discussion of the geology of the Washington quadrangle, as Carolina gneiss, which, as defined by him, is pre-Cambrian. The grounds for the assigning of such an age to rocks of this region involve the areal work of Mr Keith in the region to the north and west of Washington, which has not yet been published on account of a lack of a proper topographic base.*

STRUCTURE AND STRUCTURAL RELATIONS OF THE PIEDMONT FORMATIONS

For a proper understanding of the structural relations of the Piedmont deposits of Maryland it is necessary to recognize the character of the major structures along the eastern Atlantic coast from New Jersey southward and the position of the Maryland deposits with respect to these structures. The facts which are given below are familiar to students of American geology, but it seems desirable to restate them in relation to the Piedmont rocks under discussion.

Among the more striking features of the continental structure along

*A conference has been proposed for the workers in the Piedmont of Virginia, Maryland, Pennsylvania, and New Jersey, and an attempt will be made to reach a mutually satisfactory understanding as to the age correlations. Until this is done it is better to regard the age of the Maryland deposits as unsettled, with the evidence favoring the position taken in the preceding discussion.

	MARYLAND PIEDMONT.		PENNSYLVANIA PIEDMONT.	
	Western.	Central.	Eastern.	Southern. Eastern.
Ordovician.....	Massanutten sandstone.	Phyllite and Wissahickon schists.	Peachbottom slate.	
	Martinsburg shale.		Cardiff quartzite.	
			Wissahickon formation.	Hudson River.
Cambro-Ordovician..	Shenandoah limestone.	Cockeysville marble.		Chester Valley limestone.
	Antietam sandstone.	Setters quartzite with argillaceous upper member.		Chickies quartzite.
Cambrian.....	Harpers shale.			Cambrian.
	Weverton sandstone.			
	Loudoun formation.			
Pre-Cambrian.....	Granites, schists, etc...	Baltimore gneiss....	Baltimore gneiss....	Baltimore gneiss.. Pre-Cambrian.

the eastern coast of the continent is the generally northeasterly trend of the folds constituting the Appalachian system. This structure holds for most of the territory from Alabama to Maryland and from the Canadian boundary to New York city. In the region of Pennsylvania, however, there is a marked deflection of these parallel folds, on account of which they are found to strike almost due east and west across the state from the Potomac to the Delaware. Beyond the Delaware the formations gradually resume their northerly trend. The change in direction of the folds of the Appalachians is readily seen in the geological map issued by the state of Pennsylvania and in smaller geological maps of the United States issued in the standard text-books. For the present purpose the structure is clearly brought out by a consideration of the areal distribution of the limestone of Ordovician age, which are known by various names—Shenandoah, Lancaster, Chester Valley, Trenton, etcetera—throughout the long course of its development. A study of a map (figure 1) showing the geology of the Virginias, Maryland, and Pennsylvania permits one to trace the extent of this formation from its northeast course along the Shenandoah valley on the west side of the Blue Ridge to the north end of South mountain in the region between Chambersburg and Carlisle, Pennsylvania, where the trend changes from northeast to east. This easterly trend is pursued to Harrisburg and the vicinity of Reading, when a series of folds causes the areal distribution to extend somewhat farther north, although the structure lines still remain approximately east and west. If one disregards the overlaps of Triassic in this portion of Pennsylvania, it may be seen that the Cambro-Ordovician limestone widens by a series of folds along the Susquehanna and Schuylkill rivers and extends back southward along the eastern flank of the South mountain anticline as far as the Potomac river. Within this broad region of limestone may be noticed several anticlines of gneiss bordered by Cambrian quartzite and surrounded by the Cambro-Ordovician limestone, which in few instances appears overlain by shales and schists of Ordovician (Hudson River) age. The southernmost portion of the Cambro-Ordovician limestone appears in many cases, as at Frederick, near Strassburg, at Downingtown, and on the Schuylkill, to be on the south side of anticlines, and thereby representing the northern limb of synclinoria, which possess the general axial features noticed in the Ordovician limestone. Overlying the limestone along its southern and eastern borders are the phyllites and less crystalline representatives of the supposed very ancient members of the Piedmont plateau. Disregarding the possibility of extensive thrust faults, for which the facts in the area rarely indicate any probability, the most natural inference would be that these shaly phyllites are Ordovician deposits lying in an eastern geo-

syncline whose axis conforms to the general character of the continental structure. Such a geo-syncline would be between the Blue Ridge and Great valley on the north and west and the accumulation of metamorphosed sediments and igneous rocks on the east. This inference is, moreover, corroborated by the character of the folding where it has been deciphered in eastern and central Maryland.

The map still further shows that, while the forces at work to produce the Appalachian structure along the Atlantic coast were exerted north-

FIGURE 2.—Sketch of axial Lines for major Structures of the Piedmont.

west and southeast, the distribution of force in the Maryland Piedmont was very much more complex, since the center of the major curve of the continental structure lies approximately coincident with the city of Baltimore. This fact would seem to indicate that whatever forces were at work in the Maryland Piedmont during the formation of Appalachian structures must have worked on lines radiating from a central point, and that if any difference of force along these lines occurred there must have been developed more or less torsional stress, and that such torsional

action would be likely to produce folds of shorter major and greater minor axes than are the rule in the long-drawn-out ellipsoids of Appalachian folding. The effect of these forces must thus have a direct expression in the areal distribution of the various deposits found in the Piedmont of Maryland, and, conversely, if such results are found there is developed a reasonable probability that the present major structures of the Maryland Piedmont were produced by the same forces and at the same time as the Appalachian folds.

Starting on the west with the faulted and sharply folded anticlines of the Blue Ridge bordered on either side by Cambrian rocks and associated igneous masses (compare figures 1 and 2), one may pass successively eastward through Maryland across the gently eastward sloping limestones of the Frederick valley, which in turn, as above described, appear to dip under the so-called semi-crystallines or phyllites of the Piedmont. While the detailed structure is not fully known, it seems probable that there exists in this part of the state a very open general structure by which the beds lie almost horizontal in their major folds, with a much compressed subordinate structure, which, because of the numerous minor folds, give to the rocks an appearance of highly inclined and complicated folding. East of Parrs ridge the rocks are more crystalline and the folding a little more pronounced in its general features, with a change in strike of the axes of the major folds in conformity with the change of direction in the continental folding previously described. Between the area of open folding just described on the northwest and the cover of Coastal Plain deposits on the southeast one may readily recognize in the Maryland area the broad synclinal trough of the eastern phyllite belt and that of the Cockeysville marble, separated by the dome-like anticline of the Baltimore gneiss already described. Still farther east, separated from the Cockeysville synclinorium in part by a southern anticlinal border of Baltimore gneiss, is a broad zone of igneous rocks composed of gabbros, granites, and other plutonic types which occupy most of the eastern border of the Piedmont between Wilmington, Delaware, and Laurel, Maryland.

Minor igneous masses are found with the same general trend, and these are seen to be rather closely associated with the structure lines of the region, occupying as they generally do anticlinal axes. This relation to the structure lines is particularly shown in case of the long belt of serpentines extending from Lancaster county, Pennsylvania, across the Susquehanna river almost to the nose of the northern anticline of the Baltimore gneiss. Farther to the southwest, almost on the strike of this anticlinal axis, begins a long and somewhat narrow body of granite extending from Sykesville, on the Baltimore and Ohio railroad, southward

across the Washington quadrangle and thence continuing probably as far as the Fredericksburg region.

EASTERN PIEDMONT OF VIRGINIA

Our knowledge of the Piedmont formations in Virginia is by no means equal to that of Pennsylvania and Maryland, since little or no work has been done in the area between the Blue Ridge on the west and the Coastal Plain deposits on the east since the days of the Rogers. There have appeared, however, occasional local descriptions of limited areas, and these the present writer has attempted to correlate with the facts given in the early reports of the Virginia survey, and these correlations have in a measure been checked by personal reconnaissance as far south as the James river. It should not be thought, however, that the following statements are regarded as any more than a working hypothesis, which may aid in the ultimate interpretation of the Virginia Piedmont.

A study of the Piedmont geology of Virginia from the literature impresses the student at once with several generalizations, the strongest of which is that in all of the previous work little or no attempt has been made by the different students to recognize and map the different formations within the limits of the Piedmont east of the mountains. A second impression from the descriptions published is that formations similar to those recognized in Maryland extend across the state of Virginia with a trend similar to that of the Blue Ridge and the Shenandoah valley farther west, with the exception, however, that the limestones and marbles are apparently absent in any extensive development comparable to the areas of Cockeysville marble in the Maryland region. On the other hand, the little lenses of marble which have been recognized and but little studied in the western part of the Maryland Piedmont may be traced, where the older rocks are not obscured by the Triassic sandstones, all along the western side of the Virginia Piedmont from the Rapidan to the Staunton river and probably to the North Carolina line.

Again, it may be noticed that the igneous rocks occupy similar positions in Virginia to those in Maryland, with the exception that they are relatively less abundant, and, so far as the facts at hand indicate, are usually granite and not gabbro, although the writer has found hornblende schist in the valley of the James which probably represents metamorphosed gabbros, and the lithologic descriptions suggest that gabbroic rocks, more or less metamorphosed, may be found in several parts of the state. The principal masses of granite so far recognized are (1) the southward continuation of the granite of the Catoctin belt recognized by Keith,*

* Fourteenth Ann. Rept. U. S. Geol. Survey, pp. 285-395.

which evidently extends southward into Albemarle county; (2) the southward continuation of the Sykesville-Washington granite area, which apparently is more or less continuously developed from Washington to Fredericksburg, and possibly includes the granitic masses at Columbia, on the James river, which is approximately on the strike, according to the general trend of the formations; (3) the granitic mass in the area about Richmond, which conforms in position to the more easterly granite of the Maryland area.

When an attempt is made to decipher from the remarks and lithologic descriptions a general clue regarding the structure of the Virginia Piedmont one may be led to the following suggestions: On the west is a well defined anticline of the Blue Ridge with Cambrian and Ordovician rocks on the west and the rocks of the Piedmont on the east. Throughout most of the distance from the Potomac to the James the analogues of the Blue Ridge and Catoctin mountains of Maryland may be traced as companion topographic features. It is, however, to be noted that in passing southward these parallel ridges become separated and the easternmost less prominent and broken up, suggesting the southward dying out of the eastern part of the double-topped anticline exhibited in the Maryland area. With the Blue Ridge on the west and a southward continuation of Catoctin mountain, represented by Bull Run, Southwest, Carters, Green, and Finley mountains, on the east are associated amygdaloidal chloritic rocks representing surface flows, which have been termed by Mr Keith "Catoctin schist" and occasional meta-rhyolites. East of the more mountainous part of the Piedmont little is known of the structure in the northern part of Virginia south of the Washington sheet, but it seems reasonably probable that we have here a broad synclinal area comparable to that of the western Piedmont in Maryland. The rocks are in large degree similar and the areal distribution and position of the region with respect to the Maryland territory support this assumption.

South of the James river, if one may judge at all from the meager descriptions published, including the sections of the Virginia survey, there are a series of more sharply compressed folds, which bring to the surface more crystalline gneisses comparable in character to the Baltimore gneisses of Maryland. Associated with these are less crystalline schists similar to the Wissahickon formation of Pennsylvania and Maryland, but differing apparently by a somewhat less pronounced degree of metamorphism. It is in this area that Darton * found fossils indicating the Paleozoic age of these deposits. Southward from Amelia court-house is the suggestion of a large synclinatorium plunging to the southward along a line from Amelia, Virginia, to Warrington, North Carolina, which would

* Amer. Jour. Sci., 3d ser., vol. xliv, 1892, pp. 50-52.

explain the relative broadening of the Piedmont along the Virginia-Carolina boundary, where the structures of the west are trending southwestward and those on the east in a more southerly direction.

CONCLUSIONS

The preceding survey of the present state of knowledge regarding the formations and structure of the Piedmont in Maryland would seem to warrant the following conclusions:

(1) The four formations recognized by Doctor Bascom in the Philadelphia area may be traced across the state of Maryland, and they probably constitute the bulk of the rocks forming the Piedmont of Virginia, which have heretofore been mapped as a unit.

(2) The structural character of the Piedmont from Trenton southward to southern Virginia is similar throughout to the Appalachian structure of the less metamorphosed Paleozoics to the westward—that is, one may recognize within the Piedmont a series of long and narrow folds and arches trending parallel to the trend of the Appalachians. An exception to this general rule is noticeable in the central Maryland area, which lies toward the center of a local curve in the Appalachian structure, where the structural forms are more nearly circular than is the general rule in the Appalachians.

(3) The age of the different formations in the Piedmont is still unsettled, with the weight of opinion so far presented in favor of an early Paleozoic age for the formations immediately overlying the Baltimore gneiss.

(4) The conclusions reached, so far as they relate to Maryland, are based on a detailed mapping or intimate knowledge of practically all of the Piedmont, but those of Virginia must be regarded as merely suggestive and warranting credence only in so far as the principles of interpretation established by detailed work for part of the province permit of application to contiguous areas.