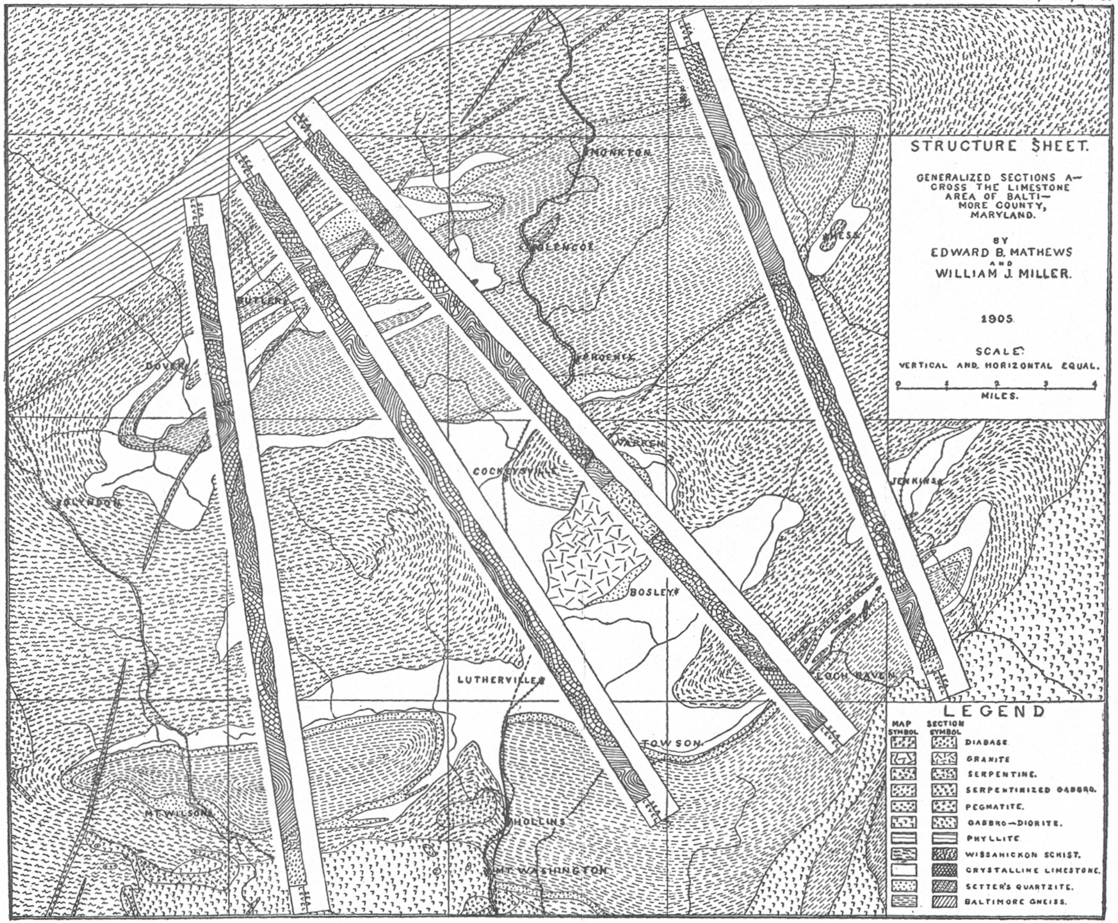

GENERALIZED SECTIONS ACROSS LIMESTONE AREA OF BALTIMORE COUNTY, MARYLAND

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COCKEYSVILLE MARBLE

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INTRODUCTION

In earlier papers* the senior author has presented an interpretation of the structure of the Piedmont region as exhibited in Maryland, and

* Amer. Jour. Sci., 4th ser., vol. xvii, pp. 141-159, 1904; see also paper in this volume, pp. 329-346.

suggested that it is possible to recognize in the highly crystalline and much metamorphosed rocks of the area lines of bedding which indicate that the crystalline rocks of the Piedmont possess a general structure comparable to that of the Appalachians lying to the westward. In the present paper it is proposed to give a somewhat more detailed discussion of a local area, the special problem of the junior author, in which the type of folding is well exhibited and more easily seen because of the sharp differences, lithological and topographical, between the limestone or marble and the adjacent rocks.

The area under discussion occupies a tract of approximately 300 square miles, represented on the southern portions of the Belair, Parkton, and Westminster sheets and the northern part of the Gunpowder, Baltimore, and Ellicott sheets of the United States Geological Survey, or, in other words, between 76 degrees 25 minutes and 76 degrees 50 minutes west longitude and 39 degrees 20 minutes and 39 degrees 40 minutes north latitude. The Northern Central railroad from Baltimore to Harrisburg passes directly across the region, while the Western Maryland from Baltimore to Hanover skirts its western limits.

Rocks of the Region

List of the Formations

Within the limits of the region under discussion are exposed the rocks of the four formations, namely, (1) Baltimore gneiss,* (2) Setters † quartzite, (3) Cockeysville † marble, (4) Wissahickon * mica-schist, mica-gneiss, and phyllite, described by the senior author in the discussions already referred to. The lithological characters of these different formations vary somewhat from place to place, but as exposed in the vicinity of the Cockeysville marble may be described as follows :

Baltimore Gneiss

This is a highly crystalline gneiss, composed of quartz, feldspar, and mica, or hornblende, with accessory minerals so distributed as to produce a well marked gray banded gneiss, the individual bands of which vary from a fraction of an inch upward. The average thickness, however, is quite small. Some of these beds are highly quartzose, resembling a micaceous quartzite or less frequently a vitreous quartzite; others are rich in biotite or hornblende, producing dark to black rocks indistinguishable in a hand specimen from the mica and hornblende schists and gneisses derived from igneous rocks by metamorphism. Through these banded gneisses are intruded pegmatite and aplitic dikes more or less

*Accepted by the Committee on Geologic Names of the U. S. Geological Survey.

† Old terms used provisionally until an agreement on names is reached.

parallel to the regular banding of the gneiss. Many of the broader bands composed usually of hornblende-schists are probably of igneous origin, as has recently been shown for similar rocks in New York by Professor Julien. The banding of these gneisses has generally been regarded as secondary, but the fact that the strike and dip of the bands coincide with the strike and dip of the sedimentary rocks around the nose of folds and on either flank makes it seem probable that they are very often, if not always, indicative of original variations in sedimentation.

SETTERS QUARTZITE

This formation as developed in its type locality, Setters ridge, in the southwest corner of the area under discussion, is a fine grained, somewhat saccharoidal, thin-bedded quartzite of white, cream, or light-brown color. The beds are usually separated by thin films of sericite in tiny glistening flakes. On the surface of these mica-covered planes frequently occur black tourmaline crystals, which, as first shown by Williams, give evidence of movement along these planes. In other portions of the area, especially in the vicinity of Butler and along the Gunpowder river west of Glencoe and east of Phœnix, the rock becomes more vitreous and less clearly bedded. This is especially true in the cutting of the Gunpowder just below Warren, where the quartzite is exposed in a double-topped anticline of moderate size.

Resting on top of the more homogeneous and quartzose members occasionally occur quartzite bands interbedded with micaceous layers, which in the hand specimen appear to be garnet schists, practically indistinguishable from the Wissahickon schist, which occurs higher in the column. At times the quartzitic layers become insignificant and the whole mass looks like a Wissahickon schist. There are, however, minor features which can not be put into words, but which may be recognized during the progress of continuous mapping, which render the aspect of the exposure and the character of the rock valuable as aids in mapping. It was at first thought that this portion of the quartzite formation was in reality a faulted-in representative of the Wissahickon, but detailed mapping of critical areas, where the formations possess more marked minor folding, show that a fault can not explain the development of this local member of the quartzite formation.

The Setters quartzite is generally found dipping at a steep angle, and because of its resistance to weathering agencies it is often a topographic feature which aids in determining its limits.

COCKEYSVILLE MARBLE

The carbonate rocks, which because of their more extensive exploitation and peculiarities in weathering have been of especial service in deciphering the structure of the Maryland area, consist of calcitic and dolomitic varieties. The main mass of the rock is magnesian and would be classed as a crystalline dolomite. This is not a mapable unit as opposed to the marbles, which are of pure calcium carbonate, and the investigations of the junior author, so far as they have progressed, do not warrant any statement indicating a stratigraphic difference in position between the lime and magnesian rich rocks. The intimacy of association may be judged from the following detailed section made by the junior author:

Section showing alternations of calcitic and dolomitic marble

	Feet	Inches
Medium grained, calcitic	5	
Rather coarse grained, clear, white, calcitic	1	2
Coarse grained, bluish, pyrite, calcitic	..	4.5
Very fine grained, friable, dolomitic	..	1.5
Very pure, coarse grained, calcitic	..	6
Fine grained, gray, micaceous, dolomitic	..	10
Fine grained, grayish brown, impure, calcitic	..	4
Fine grained, pure, dolomitic	..	6
Medium grained, blue, calcitic	1	8
Medium to coarse grained, white, calcitic	..	10
Fine grained, pure, dolomitic	..	7
Medium grained, blue, calcitic	1	5
Fine grained, white, dolomitic	..	5
Medium to coarse grained, brown, calcitic	1	
Medium grained, impure, bluish, calcitic	1	6
Fine grained, micaceous, gray, dolomitic	2	
Medium grained, pale blue, impure, calcitic	1	8
Coarse grained, white, calcitic	2	
Fine grained, brown, dolomitic	1	5
Medium to coarse grained, calcitic	1	11
Very coarse grained, white, calcitic	..	9
Fine grained, brown, dolomitic	..	2.5
Medium grained, blue brown, calcitic	4	6
Fine grained, micaceous, white, dolomitic	..	2
Coarse grained, pure, calcitic	..	5
Fine grained, micaceous, dolomitic	..	2
Coarse grained, white, calcitic	..	4
Fine grained, micaceous, dolomitic	..	1
Coarse grained, pure, white, calcitic	1	
Fine grained, pure, dolomitic	1	2
Fine grained, micaceous, dolomitic	6	
Fine grained, brown, dolomitic	..	7
Coarse grained, pure, friable, calcitic	2	
Fine grained, brown, dolomitic	1	
Coarse grained, pure, calcitic	..	1.5
Fine grained, brown, micaceous, dolomitic	..	3

	Feet	Inches
Coarse grained, pure, calcitic	..	10
Fine grained, micaceous, dolomitic	2	
Faulted, beds disturbed, calcite veins	10	
Fine grained, dolomitic beds	12	
Medium grained, light blue, calcitic	4	
Total	73	

The different layers within the formation vary widely in coarseness of grain from the fine, almost statuary, marble obtained at the Beaver Dam quarries at Cockeysville to the coarse so-called alum stone, in which the invividual grains may reach a diameter of one-half, three-fourths, or even 1¾ inches, as is found in many parts of the region. So far as any generalizations can be drawn regarding the variations of texture, it appears that the dolomitic or magnesian-rich varieties are finer grained and more compact as compared with the purer lime carbonate rocks, which are generally coarsely crystalline. Another feature of these rocks is the presence of impurities along fairly well defined lines which have for the most part been recrystallized into magnesium silicates. These lines of impurity may separate the different lime-rich beds from those rich in magnesium, or, what is more commonly the case, dolomitic layers from each other. It seems to be rather generally the rule that the impurities are more intimately associated with the layers rich in magnesium than with those rich in lime, but frequent exceptions may be found to this statement. Among the most common accessory minerals found in this formation are phlogopite, biotite, muscovite, and iron pyrites; tremolite, quartz, and occasional tourmaline are, however, more frequently found within the limits of individual beds.

The general rule employed in field work, based upon innumerable acid tests, has been that the coarser grained beds are calcitic and the fine grained beds are dolomitic; each type is white, cream, brown, or somewhat dirty in color.

WISSAHICKON SCHIST

This formation consists of a series of highly micaceous, very schistose, and often crinkled aggregates of quartz, more or less chloritized biotite and garnet, with accessory orthoclase, cyanite, staurolite, etcetera. With the increase of feldspar the rock passes into a gneiss. This, however, is less distinctly banded than the gneisses of the Baltimore formation. The individual beds in this type are only indistinctly marked, and their separation from the well-defined lines of foliation is often attended with considerable difficulty. The dip of the foliation varies somewhat, but is usually about 45 degrees, while the effective dip of the individual beds, which themselves are highly crinkled, may vary from 0 to 90 degrees, representing in their general structure open folding, but in their intimate structure the folds are frequently much compressed and often overturned and slightly faulted.

IGNEOUS ROCKS

Through these several sedimentary formations have been intruded igneous rocks ranging in composition from granites to peridotites. The main development of the igneous rocks, however, lies outside of the field selected, only the extreme members being represented, in the granite between Warren and Cockeysville and in the serpentinized peridotite of the Bare hills. These igneous rocks were intruded either during the folding of the rocks or subsequently.

There are also several lines of diabase boulders representing dikes which have been correlated with the great Triassic intrusions farther north.

Areal Distribution of the Rocks

IN GENERAL

The rocks of the region, as shown by the accompanying sketch map (figure 1), may be roughly grouped into three broad belts extending parallel to the strike of the formations from northeast to southwest. On the south are two anticlinal areas of the Baltimore gneiss, separated from each other along the strike by a fault and sharp folding, while on the north is an oval anticlinal area of Baltimore gneiss about 15 miles in length and 5 miles in breadth in its widest point. Between these two areas in a broad synclinal trough occur in regular succession the Setters quartzite, Cockeysville marble, and Wissahickon schist, the latter occupying the larger portions of the area and connecting on the north, east, and west with the larger body of Wissahickon, which extends diagonally across Maryland from the southwestward continuation of the type Wissahickon of Pennsylvania to the Potomac river on the west.

DISTRIBUTION OF BALTIMORE GNEISS

Southern area.—The southern development of the Baltimore gneiss on the south side of the Greenspring and Mine Branch valleys falls into two distinct areas, separated by the limestone and Wissahickon valley of lake Roland and possibly by a fault. On the west is a lenticular anticlinal mass entirely surrounded by the Setters Ridge quartzite, wherein the bands of Baltimore gness stand at a high angle, ranging from 40 to 75 degrees at the center, and strike parallel to the major axis of the ellipse except near the ends, where their strike follows the general contour of the areal distribution, and the dip lessens to between 10 and 30 degrees. The exposures within this area, which rises to the level of the Piedmont plateau, are not good, and it is not possible to make a detailed correlation of any of the beds found within it. The facts observed, however, clearly indicate that we have here, as is so often the case, an anticlinal zone which plunges downward at either end. The best exposures of the formation are those along the northern part of Park Heights avenue between Eccleston and the road from Pikesville to Rockland, which is known locally as the " Old court road."

The eastern half of the Baltimore gneisses on the southern borders of the area extends from the north and south fault along the Northern Central railroad between Hollins and Sherwood eastward to Towson, and thence across the Gunpowder river to the vicinity of Glenarm, where it terminates in a steep, tightly pinched anticline. On the south the limits of the Baltimore gneiss have not been entirely worked out, but the detailed mapping of the late Professor Williams would indicate that it is bordered by the quartzite which extends from the Northern Central railroad near Mount Washington to lake Montebello, within the northeastern limits of the city of Baltimore, where the crystalline rocks are covered by the later unconsolidated deposits of the Coastal plain. On the east this formation is bordered at first by the quartzite and limestone, but these successively pinch out within a mile or two of the eastern nose of the anticline, and do not appear along the deeply cut trench of the Big Gunpowder river. It is probable that the southern limit is a a strike fault or the contact with the large gabbro mass which extends in a northeasterly direction across Maryland from the eastern limits of Baltimore city to the Susquehanna river near Darlington. Throughout this region of Baltimore gneiss the exposures are poor, due to the high state of cultivation of the land, its plateau-like character, and the presence of numerous well kept country estates. There are, however, numerous exposures along the Gunpowder and in some of the other streams, but the gneisses at this point are intricately penetrated by numerous granitic and grabbroic intrusions.

Northern area.—The northern area of Baltimore gneiss is broadly an ellipsoidal mass, representing a large anticlinal dome, which, like the smaller one of the south, plunges at either end. This plunging of the anticline to the westward brings the overlying formation down to the surface of the country, and thereby causes the surface exposure of the Baltimore gneiss to narrow rapidly to the westward of the Northern Central railroad. The marked differences in character between the quartzites, limestones, and Wissahickon schists allow the working out of the structure in greater detail than is possible in the eastern half of this anticlinal dome; but the observations within the Baltimore gneiss in the eastern half of the lenticular area, to the eastward of Monkton and Phœnix, are entirely in accord with those of the western portion, and indicate that the gneisses occur in numerous tightly pinched folds, possessing a common strike parallel to the major axis of the dome and steep dips, some of the time to the north and some of the time to the south. On the whole, the northerly dips predominate, indicating that the anticline is somewhat overturned to the south.

Numerous exposures of the gneiss are found along the Big and Little Gunpowder rivers and their tributaries, but they are few and unsatisfactory, except for areal mapping, in the plateau portions of the region which is a prosperous farming community under a good state of cultivation. The exposures encountered show that the Baltimore gneiss is penetrated in the northern area by igneous intrusions, now much metamorphosed, of granitic and gabbroic materials. The former are altered to granite-gneisses and the latter to hornblende-schists.

DISTRIBUTION OF SETTERS QUARTZITE

General characteristics of the exposures.—This quartzite formation, with its local variations toward a garnet-schist, occurs on the borders of the Baltimore gneiss area, usually as long, narrow ridges, rising steeply from the level of the limestone valleys to the surface of the plateau or upland, and usually may be found outcropping where the streams have cut across the strike. Its exposures are highly characteristic, though generally poor, on account of the small rhomboidal form of the fragments into which it breaks when fine bedded and somewhat micaceous. When highly quartzose and more compact it is likely to be confused with the Baltimore gneiss, and when very micaceous and carrying garnets it is likely to be confused with the Wissahickon schists which overlie the limestones.

Southern area.—The ocurrence of the quartzite about the Baltimore gneiss dome in the southwestern part of the area may be traced almost continuously, by means of fragments, around the entire zone, and exposures in which it is possible to obtain the dip and strike of the beds may be found frequently. In this area, the typical area for this formation, the rock is characteristically thin-bedded, the beds being separated by films of sericitic mica. Along the northern border of the anticline from Rockland to Red Run the rock dips uniformly northward underneath the marble at an inclination of about 70 degrees. On the south the dips are less uniform, being sometimes to the north, but generally to the south, indicating a minor folding in the beds and some overturning, as is brought out more clearly by the small stringers of marble found infolded with them. On the end of the anticline to the west the beds change rapidly in strike from east-northeast to northeast, through north and northwest to west-northwest. On the eastern end the strikes of the beds change similarly from east-northeast to northwest, through north to north 45 degrees east, the dips in all cases being away from the underlying Baltimore gneiss and beneath the overlying marble or Wissahickon schists, as the case may be.

The eastern exposures of quartzite forming the ridge on the south side of the limestone valley extending from Sherwood to Glenarm are less satisfactory than those just described, but wherever observed indicate a northern dip of somewhat less inclination until near the eastern end of the anticlinal fold, where the beds rise steeply on the north with a northerly dip of 75 degrees and an easterly dip on the south of about 40 degrees. The anticlinal character of the structure at this point is usually well brought out for Piedmont conditions by the formation of a triangular hill of quartzite produced by the nose of the fold, which is cut through by Long Green creek about a mile from its apex. The strikes of the quartzite may be traced at this point along the top of the ridge, where they show progressive changes in position through all azimuths from north 45 degrees east, through west and north, to north 30 degrees east, and even reach north 60 degrees west near the crossing of the Harford turnpike. The character of the quartzite in this part of the fold is not that typical of Setters ridge, but shows the development of more mica with accessory garnets and occasional cyanite.

Throughout this entire southern region the quartzite shows the average thickness of about 500 feet.

Northern area.—The areal distribution of the quartzite about the northern dome of Baltimore gneiss is much less constant than is the case about the southern areas, and there are many evidences of a marked erosional conformity and a few strike faults in this part of the region. The occurrence of the quartzite may be traced almost continuously from a few miles west of the Northern Central railroad near Cockeysville along the southern side of the road to the northeastern nose of the fold on the road between Taylor and Jarrettsville, where a well defined V-shaped hill is formed by the upturned beds of the quartzite, and thence westerly on the northern side of the dome. The quartzite is not distinguished in the cut of the Northern Central railroad north of Monkton, but the typical tourmaline-bearing mica-schist is found outcropping on the hills across the river, and thence may be traced along the westerly side of the dome in several bands to the southwestern nose of the anticline, where it may be found in a few poorly developed exposures. The exposures along the northern boundary east of the Northern Central railroad are very poor, and the presence of the quartzite is only actually established at a few points, owing to the cover of soil and the close similarity of the Baltimore gneiss at this point. It is quite possible that the quartzite is cut out locally, as it can not be recognized in the well exposed cuts along the railroads just north of Monkton. If this is so, the lack of quartzite only occurs for a short distance along the strike, as it is exposed in the road from Monkton to Hereford, just west of the Gunpowder river, and from this point may be traced without interruption through Pine Hill to the sharply folded region between there and Glyndon.

Along the southwestern limits of the Baltimore gneiss the quartzite is seldom found between it and the overlying marble, and wherever so found it is usually very thin and poorly developed. It has been noted along the northern edge of the Worthington valley near Councilmans run and a little farther north above Slades run, but is apparently lacking along the contact between the limestone and the Baltimore gneiss as exposed along Western run. Such a rapid thinning of the quartzite from a thousand feet or more in the ridges between Butler and Stringtown to zero in Western run, a distance of less than 2 miles across the strike of the folds, is quite unusual, but no facts were found indicating a fault, and many observations point to a rapid thinning, due apparently to an erosional unconformity.

The unusual and rather peculiar development of garnet-schists and garnet-mica-schists interbedded with the quartzite and apparently constituting an upper member of that formation is best exhibited in this northern region, especially between Pine hill and a point 1 mile northwest of Butler, in the Stringtown valley. The quartzitic layers at this point are not well developed, and the outcrops along the sides of the hill strongly suggest the Wissahickon schist. The true position of this bed is, however, shown by the folding of the quartzite-garnet rock and limestone northwest of Belfast along Buffalo creek, where the areal distribution and structural observations seem to exclude the possibility of a fault and demand the interpolation of an upper member in the quartzite formation. This same conclusion is the most satisfactory deduction from the observations made in the quartzite formation along the gorge of the Gunpowder between Warren and Royston branch, where the garnetiferous rock interbedded with quartzitic layers is found resting on more quartzose beds, and beneath the marble the whole conforming with the structural relations shown by numerous exposures of marble in the valley of Royston branch. The detailed character of the structure at this latter point will be more fully discussed in a later portion of the paper.

DISTRIBUTION OF COCKEYSVILLE MARBLE

Areas in general.—The Cockeysville marble lies in a synclinal trough between the southern and northern Baltimore gneiss areas and in the synclinal folds on the northwest side of the northern anticline and outcrops frequently within the limits thus outlined wherever the formation is not covered by the Wissahickon schist. The occurrence of the carbonate rocks at the surface is always marked topographically by the occurrence of limestone valleys, most prominent among which are the Greenspring and Mine Bank valleys, lying to the north of the southern Baltimore gneiss, between it and the overlying Wissahickon. Between these two valleys and the corresponding valleys farther north the Wissahickon gneiss has been removed, giving a very low divide in the drainage system underlain by crystalline limestones extending from Lutherville to Cockeysville. This, together with the narrow portion of the Worthington valley and that of Green run, which border on the southern flank of the northern anticline, represent crudely a recumbent letter H. The limestone also extends northeastward from Lutherville, forming the Dulany valley, which in turn has a small offshoot of the limestone (the complementary flank of a small anticline) which runs up the valley of the Gunpowder to the mouth of Royston branch, where the limestone leaves the Gunpowder valley and occurs in a gentle anticline in the valley of the smaller stream.

From the western end of the Worthington valley the limestone wraps around the narrow nose of the northern anticline and outcrops in a series of narrow parallel valleys, separated by anticlinal ridges of quartzite and gneiss or synclinal areas of Wissahickon schist.

Beside these larger areas, which may be traced as one continuous mass, there are three smaller areas, separated from the larger. The largest of these is that forming the Long Green valley, which apparently is only a portion of the Dulany valley and Glenarm bodies, from which it is separated on the higher land by the overlying Wissahickon schist. The second area lies south of Taylor, and is apparently separated from the Green Run arm of the main mass by a strike fault. The third area is represented by a single cutcrop of very small extent, occurring beside the road just east of Glencoe station.

Greenspring valley.—The marbles of the Greenspring valley extend from west of the Reisterstown turnpike and the Western Maryland railroad eastward to the Northern Central railroad, where the valley broadens, reaching out into the various valleys already described. The marbles in this region are found in small outcrops, where they strike parallel with the axis of the valley and dip northward at a decreasing angle as one passes from the south and west to the limits of the overlying Wissahickon formation. The dip is, however, generally steeper than 45 degrees. As the limestone circles round the southwestern anticline the strikes change in conformity with the contour of the major fold, and the dip is uniformly away from the quartzite and beneath the Wissahickon schist lying to the west of Lake Roland. Between the eastern and western ends of the anticline the limestone is compressed within minor folds in the quartzite at Mount Wilson and in several places along Moores branch. It is lacking, however, in its normal position (between the quartzite and the Wissahickon) from a point 1 mile east of Cockeysville to the western limit of the fold, with the exception of the single exposure, already referred to, occurring at Mount Wilson. In the valley above Lake Roland the limestone is only exposed once or twice, as at the junction of Jones falls and Roland run. Such structural observations as can be made are in accord with the synclinal structure of this small southern offshoot of the Greenspring valley. The limits of the limestone south of the Greenspring valley are determined on the east by a north and south fault passing from Sherwood through Ruxton to Lake Roland and thence into the lowland above Mount Washington. The exposures of marble from Sherwood to Glenarm show relatively simple monoclinal dips to the northward, except in the region southwest of the Wissahickon, where this marble unites with that of the Dulany valley, and in the vicinity of Glenarm, where the limestones fold sharply around the upturned anticline of quartzite already described. At each of these points there is minor folding, and the local structure is much confused in its detail, although harmonizing well with the broader structure as here outlined. The exposures for the most part are poor and occur almost exclusively in small private openings, where the stone has been extracted for lime.

Dulany valley.—This valley, which extends for 5 miles northeasterly of Lutherville, with an average width of from 1 to 2 miles, shows numerous exposures west of the Gunpowder river, but is almost entirely lacking in the same from the Gunpowder to its easternmost limit. Enough observations, however, have been made to show that the limestone is here very flat, with several minor crests and folds extending parallel to the longer diameter of the valley, the limestone dipping beneath the Wissahickon on the north at a varying angle.

North of Merediths bridge, where the Jarrettsville turnpike rises from the limestone valley to the level of the plateau, the strike of the limestone changes rapidly through west and northwest to a little east of north, following the course of the Gunpowder river. From the vicinity of

Overshot run the strikes again change to west of north, following the course of the Gunpowder and Royston branch, the latter curving with the limestone as it wraps around the small anticline near Warren. The dip on the east side of Gunpowder valley is northeasterly under the Wissahickon, in all instances observed, but along the west side there seems to be some slight overturning, the limestones dipping at times to the westward beneath the quartzite, which normally lies below the limestone. The exposures in this offshoot from the main limestone valley are rather better than usual, and show with unusual clearness for Piedmont conditions the shifting stripes and dips due to the folding of the region. This is particularly true in the area northeast of Warren, which is discussed more fully at another place.

Worthington valley—Butler area.—The marbles which are so well developed in the valley between Lutherville and Cockeysville extend westward from the latter point along the south side of the northern anticlinal dome, widening about 5 miles west of Cockeysville into the Worthington valley, which is in reality the southwestern nose of the northern anticline, as already described. The exposures of limestone in the narrower portions of the valley are rather unsatisfactory, but show an east-and-west strike and a dip of 40 to 60 degrees away from the Baltimore gneiss and beneath the Wissahickon schists on the south. In the wider portion of the valley the dips become much less, reaching as low as 5 and 10 degrees. The strike also changes, as the limestone of the valley wraps around the anticlinal axis, from east to west and northwest and north to east of north. In this part of Worthington valley the natural exposures are few, but the solid rock has been exposed in many places by small quarries made for the extracting of limestone for agricultural purposes.

Extending northeastward from Worthington valley the limestone is found in three well defined bands forming narrow valleys. These different bands are representatives of the same formation brought to the surface again and again by the folding of the beds along the level of the present surface of the country. The dips are often steep and sometimes overturned, but the bands unite to form a continuous valley in their southwestern limits. The strike in every instance appears to be parallel to the valleys. The more southerly bands are separated by a synclinal of the overlying Wissahickon, and are in turn separated from the northernmost bands by a tightly compressed anticline exposing the Cambrian quartzite and the underlying Baltimore gneiss. These limestone areas do not extend east of the Northern Central railroad, and in only one instance are they found east of the Baltimore and York turnpike. The relations existing along their eastern limit are not determined with entire satisfaction. The areal distribution, dips, and strikes suggest that we have here the emergence of a syncline above the surface of the country, but the underlying quartzite which one would naturally expect to find bordering the limestone is absent, and the cause for this absence is not entirely evident. It is easily recognized in the field that the quartzite formation is thinning rapidly as one passes across the strike from the broad exposures in the hills south of Stringtown to the thinner development bordering the Butler-Belfast valley. Moreover, to the southward the limestone rests immediately on the Baltimore gneiss. These facts would seem to indicate that the quartzite did not extend over the entire area of the Baltimore gneiss beneath the marble at the time when the limestone was laid down. If this inference is true, it is easy to explain the non-occurrence of the quartzite on the eastern border of the limestone, and possibly to define the limits of deposition of the quartzite in this local area. Unfortunately, as is so often the case in the southern Piedmont, the exposures along contacts are very poor and frequently wanting at the critical point.

DISTRIBUTION OF WISSAHICKON FORMATION

The Wissahickon formation, which overlies the marble, occupies the remainder of the region, occurring in broad areas between the different limestone valleys already described. The schists and gneisses of the formation extend entirely around the northern anticline and occupy very much of the region between it and the southern anticline. The removal of the Wissahickon across the axis of the synclinorium along the course of the Northern Central railroad between Lutherville and Cockeysville separates the Wissahickon, however, into an eastern and western portion. The western representative of the Wissahickon, lying between the northern and southern anticlines and the Western Maryland and Northern Central railroads, forms a series of well rounded hills, which reach to the level of the plateau along their summits. The exposures throughout this region are poor, the material of the Wissahickon formation yielding a good soil and breaking down easily to a protecting mantle over the readily disintegrating garnet mica-schists. It is possible, however, to recognize that in this general basin are one or two minor folds, giving an anticline across the area a little south of the center and two minor synclinal axes just within the limits of the Wissahickon-Cockeysville marble contact.

The more eastern area of Wissahickon lying on either side of Dulany valley and extending thence northeast appears to be somewhat more complex. The rocks in the area about Loch Raven appear more gneissic and even approach the Baltimore gneiss in appearance, while the schists on the north side of Dulany valley in the vicinity of Blenheim differ somewhat from those exposed farther west. The change is due in part to the presence of a small area of intrusive meta-gabbro.

The dips and strikes, as is customary in the Wissahickon formation, are rather variable; but in their cumulative effect they show a syncline overturned to the southward in the vicinity of Loch Raven and a gentle normal syncline forming the ridge in the vicinity of the Jarrettsville turnpike. Farther westward in the high land between Royston branch and Green run the structure is more complex, and will be described in more detail when discussing the structure in the vicinity of Warren.

Structure

General Characteristics

The structure of the Cockeysville marble area is not thoroughly understood without a consideration of its relations to the general structure of the eastern part of the continent.* As is well known, the general tectonic lines extend northeast from the south across Virginia until they reach the limits of Maryland, when the strike of the various formations is deflected to a more easterly position, sometimes even becoming east and west. This general easterly trend of the formations passes in a broad band, reaching from central Pennsylvania to the Atlantic, and gradually returns in New Jersey and New York to its original northeasterly trend. The Maryland area, and particularly that portion north of Baltimore, is in the concave side of this major fold, a fact which explains certain of the structures found within this area, which appear to be somewhat unlike those described from other parts of the Piedmont and which doubtless led the late Professor Williams to an accentuation of the oval-shaped figures for his different formations. The occurrence of the various forces involved in the curvature of the general structure have produced locally within the Maryland area conditions favorable to torsional deformation, since the lines of distribution of the forces are not parallel, but slightly inclined to each other. It is for this reason, in part, at least, that the various folds, which are usually very long and narrow throughout the Appalachian region, are here rather short and dome-like, with intervening areas of less compressed folding. The effects of these differences in conditions will be brought out more fully in discussing the faulting.

The structural character of the Cockeysville region has already been given in describing the areal distribution of the various formations, but it is well to recall the fact that it consists essentially of anticlinal domes

*These are more fully discussed by the senior author in the preceding paper, pp. 334–335.

separated on their sides by synclinoria, the axes of which run parallel to the general structure of the larger folds, which are found farther to the north and west, where they partake of the structural characteristics of the eastern portion of the continent.

FOLDING

The folding of the rocks within the region, as opposed to the minor textual features, such as crinkling, cleavage, and schistosity, may be broadly characterized as consisting of a series of open folds of simple character, the individual portions of which are marked by numerous sharply compressed smaller folds, with axes parallel to those of the general structure.

The character of the folding is most readily seen by an examination of a few exceptional localities and the areal distribution of the various formations involved. It is not easy, usually, to recognize the structural characteristics from given exposures, though these may generally be detected within the individual formations when the general structural lines have been determined. This fact has rendered most attempts to work from the more detailed to the more general barren of structural results.

The simple open character of the major folding is well indicated in the structural sections across the face of the accompanying map, but the detailed complexity of this exceedingly intricate region is only shown diagrammatically.

A feature of the folding which should not be overlooked is a tendency toward unsymmetrical folds and often to overturned folds. The unsymmetrical folding seems to be a property characteristic for the entire regions, though never very sharply brought out, while the overturned fold is a feature of local development, as along the south border of the southwest anticlinal dome, where there is an intertonguing of the quartzite and marble, with dips indicating overturned folds. This overturning is also shown in many minor folds of the northern anticlinal dome, but the similarity of the beds and the poor exposures in this area render it difficult to do more than decipher the local structure here and there. The intervening well cultivated fields or soil-clad forested areas make it impossible to carry minor structures across the folds.

FAULTING

The faulting in the area, so far as it is seen, introduces one of the most interesting structural features noticed and brings out the influence of the continental structures on this region. Although many small faults of slight throw may be detected during the course of field study, only three faults of considerable magnitude have been noted, and these are not very clearly shown except by the areal distribution and contiguous structural details. These faults, as shown on the general map, lie in a curved line passing from the Little Gunpowder near Hess to the valley

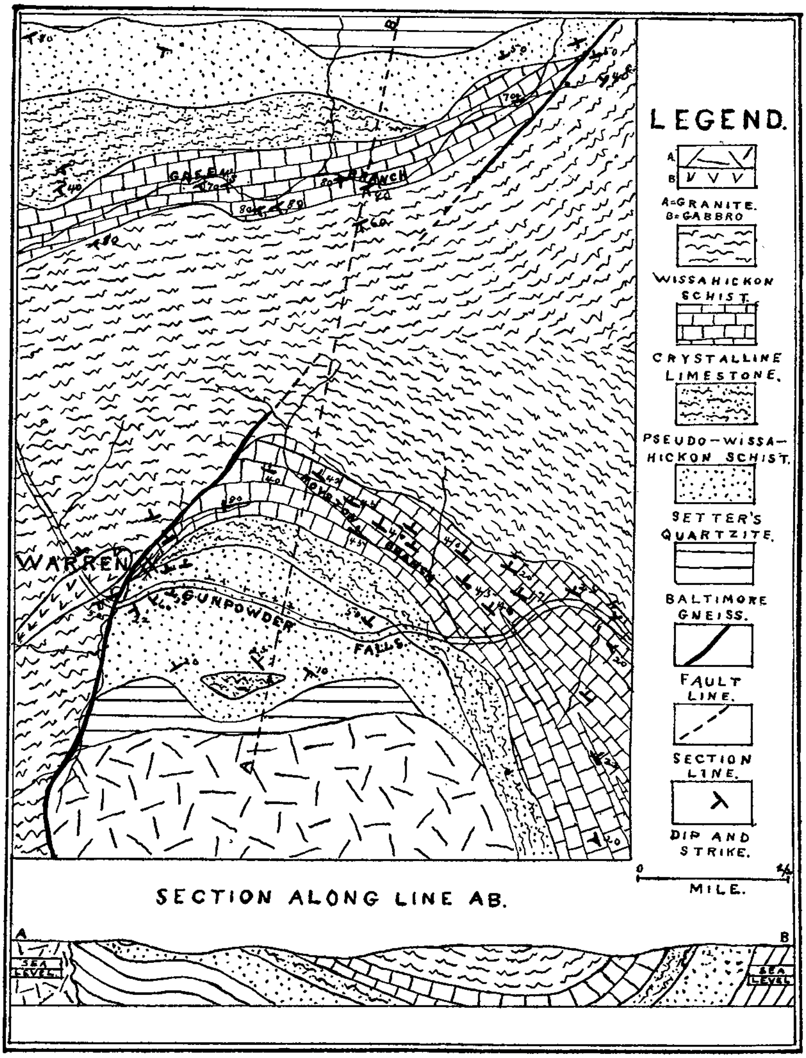

FIGURE 1.—*Map of Vicinity of Warren.*

of Jones falls in the vicinity of Mount Washington. They are all in the nature of thrust faults, but the almost complete absence of anything approaching contacts renders it difficult to demonstrate this fact. There is, moreover, a torsional feature in these faults which is of especial interest. The thrust at the northern end of the fault is slightly to the eastward, as in the vicinity southwest of Hess, where the Setters quartzite may be found above the Wissahickon and limestone if the latter is present. Along the central and southern portions of the fault line, however, the thrust is westward. The relationships may be most thoroughly studied in the valley of the Gunpowder at Warren, where it is quite clearly shown that we have a somewhat complex anticline plunging to the northward with a compressed fold in a line passing through the town of Warren.

The anticlinal character of the folding is evident (figure 2) east of Warren near the mouth of Royston branch, where the Gunpowder flows in a gorge cut through the Setters quartzite and "pseudo Wissahickon" (the garnetiferous upper portion of the quartzite formation) and Cockeysville marble to the contact between the latter and the underlying Wissahickon, which it follows southward to Dulany valley. The strikes and dips as shown in the valley of Royston branch indicate at this point a northward plunging anticline, the west limb of which is replaced by the fault under discussion. The Wissahickon schists may be traced continuously around the anticline to the Gunpowder river immediately west of Warren bridge, where they are found striking to the south and dipping to the west or east, as the case may be. Near the quartzite on the south side of the Gunpowder the strike is southwesterly, and the dip is toward the east as a result, apparently of the overriding of the quartzite at this point. In the stream bottom beside the road leading from Warren to Cockeysville on the line of the fault is a recemented breccia, which indicates a portion, at least, of the fault zone.

The structural features of this locality indicate that the forces at work were northwest and southeast, and that the thrust, which here is slight as compared with that farther south, carried the Baltimore gneiss, quartzite, and marble across the Wissahickon formation.

The structural features along the southward continuation of this fault are much obscured by the intrusion of a granite mass which forms the eastern boundary of the Wissahickon and probably occupies the eastern side of the fault, where one would naturally expect the Baltimore gneiss if there had been no granitic intrusion.

The southern fault, which extends from near Lutherville to south of Mount Washington, is similar in character to that already described about Warren, but much more pronounced.

The accompanying sketch map* (figure 2) of the valley of Jones falls

*The relative position of the detailed maps may be indicated approximately by placing the southwest corner of the neat line of figure 1 over the northeast corner of figure 2. Both figures oriented north and south.

between Rockland and Hollins, two stations on the Northern Central railroad, shows in detail the complexity of the structure in this area as well as the observations on which the present interpretation is based.

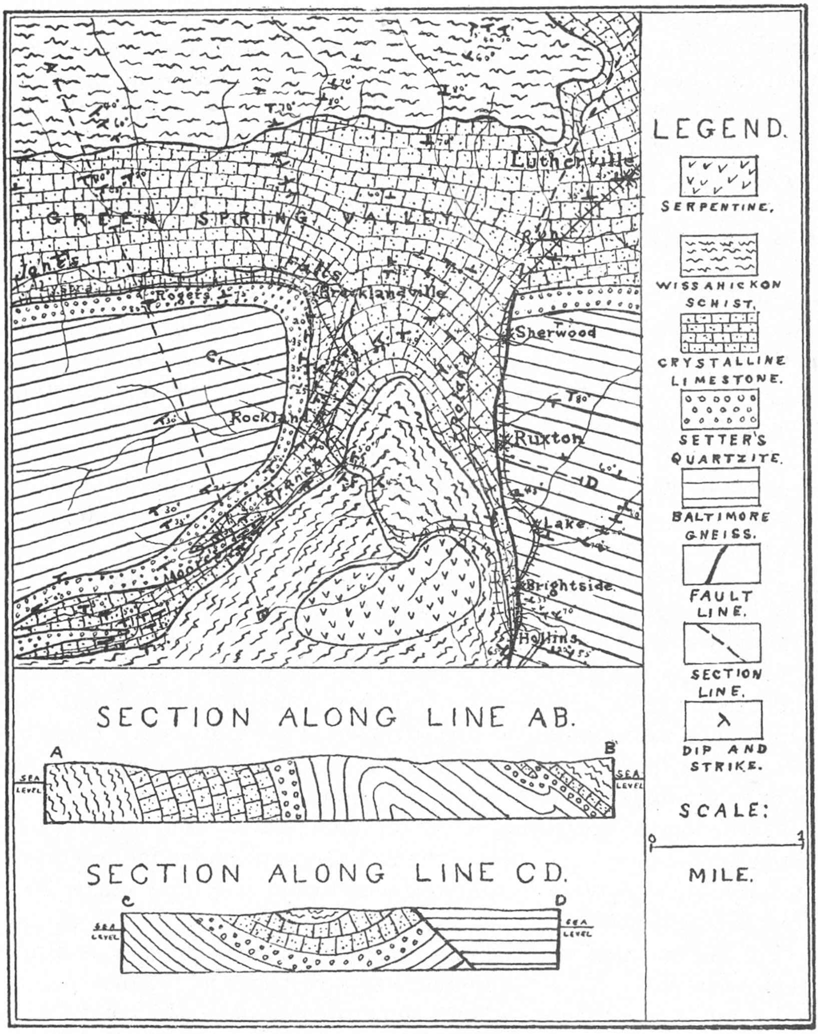

FIGURE 2.—*Map af Vicinity of Rockland.*

On the west is the eastern end of the southwestern anticlinal dome already described, and on the east the southerly extension of the fault under discussion. Earlier work in the region led Doctor Williams to interpret the eastern termination of the western anticline as a fault complementary to the fault recognized by him and the authors on the eastern side of the valley. It was supposed by Professor Williams that this valley represented a faulted block of limestone. That such is not the case is well shown by observations recorded in the accompanying map, where the strikes and dips may be traced with constantly changing azimuth about the nose of the anticline from Rogers station to the southwestern corner of the sketch map. The structural details in the center of the valley in the limestone indicating a southward plunging syncline also corroborate the later interpretation. The original view evidently arose from the failure to recognize the difference between the overlying Wissahickon and the underlying Baltimore gneiss.

Although no exposures are found along the actual fault line between Sherwood and Brightside, the sharp divergence in strike and dip as well as the difference in character of the rock leaves no doubt as to the occurrence of a fault at this point. The ends of the various beds of the Baltimore gneiss strike northwesterly against the limestone and Wissahickon, which have a more southerly trend and a dip to the westward.

The westward thrust of the eastern anticline widens very perceptibly (see general map, plate 65), the distance between the quartzite areas representing the limbs of the anticline. They are fully twice as far apart as in the corresponding anticlinal dome on the western side of the valley. If the foregoing parts of what appears to be a single fault zone be regarded as separate faults, they may be characterized as follows: The northernmost fault differs from each of the others in some particulars and in other particulars is like them. Like the Warren fault, it occurs parallel to the strike of the major anticlinal dome, but, unlike both the Warren and Ruxton faults, the thrust is toward the southeast. This difference in the direction of the thrust within the distance of a few miles would be a serious matter to explain without a knowledge of the continental structure to the westward. With these facts at hand the relationships become clearer. All three of the faults show the older, more crystalline, and more competent Baltimore gneiss thrust over the younger and more yielding marbles and Wissahickon schist. In the faulting the quartzite is associated with the underlying gneiss, with which it is lithologically very similar. The difference in thrust at the different points may be produced by the slightly divergent lines of force which have produced compression and local glancing blows resulting in a small amount of contortion. Thus on the north the Baltimore gneiss is shoved southward and on the south it is shoved northward, while in between is a less marked faulting, which partakes of the westerly thrust from the south, but is here not as strongly marked.