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CHARLES D. WALCOTT, DIRECTOR

THE CAMBRIAN ROCKS OF PENNSYLVANIA

BY

CHARLES DOOLITTLE WALCOTT

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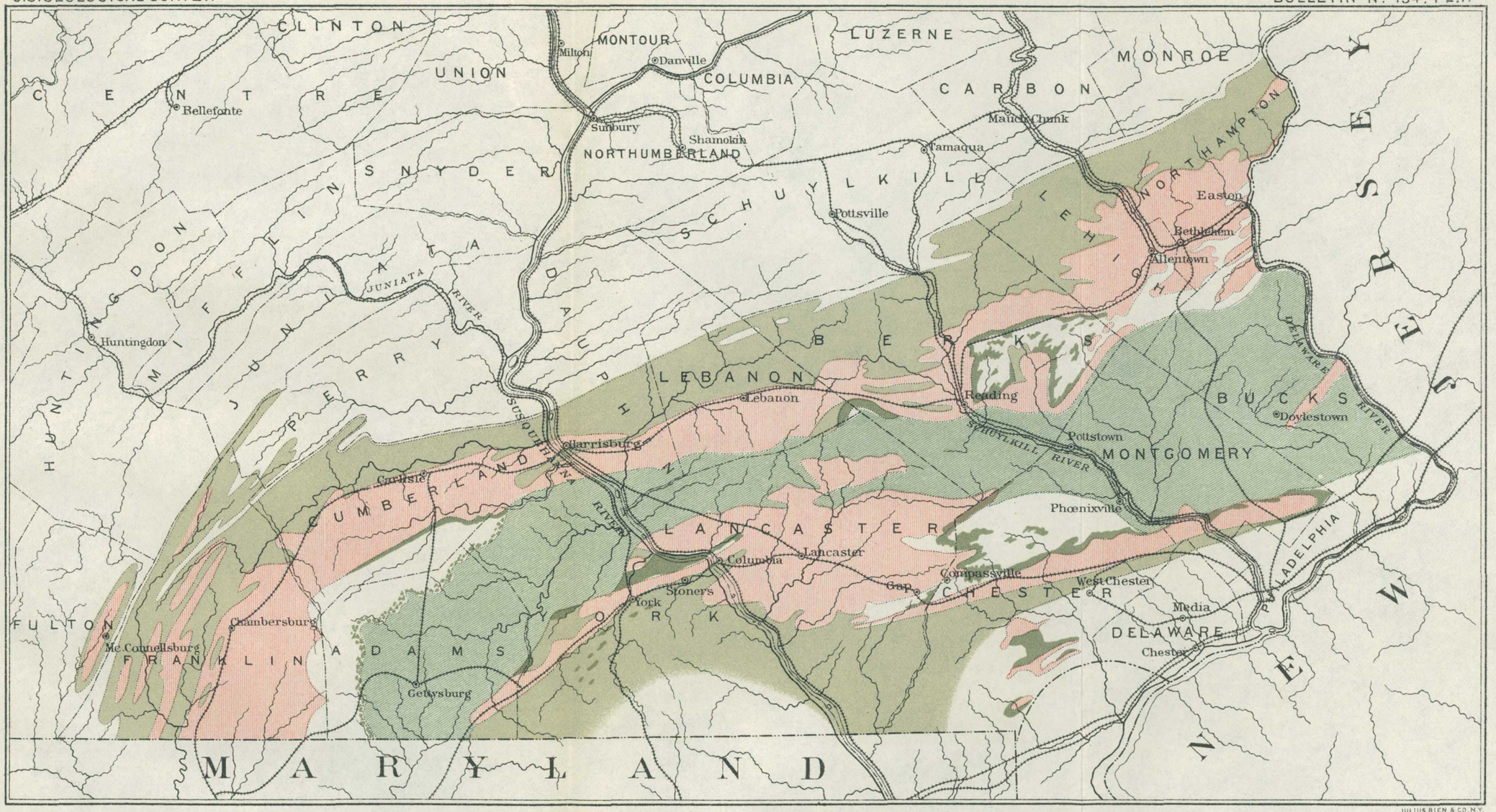

GEOLOGIC SKETCH MAP OF SOUTHEASTERN PENNSYLVANIA

AFTER SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

MESOZOIC | SILURIAN (ORDOVICIAN) | SILURIAN (ORDOVICIAN) / CAMBRIAN (LIMESTONE) | CAMBRIAN (QUARTZITE)

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THE CAMBRIAN ROCKS OF PENNSYLVANIA.[1]

BY CHARLES D. WALCOTT.

INTRODUCTION.

Prior to 1892 the strata in Pennsylvania referred to the Cambrian system included the Primal Quartzite of Professor Rogers, and Prof. J. P. Lesley was inclined to consider the sandstone and slate of the South Mountain proper as of Cambrian age. The line of outcrop of the Primal Quartzite extends along the boundaries of the various Archean areas from the Delaware River on the northeast, in Bucks, Lehigh, and Northampton counties, southwesterly, with more or less interruption, across Berks, Montgomery, Chester, Lancaster, Lebanon, York, Cumberland, Adams, and Franklin counties to the Maryland line. Prof. J. P. Lesley's summary of the formation is as follows:

The lowest Paleozoic formation in Pennsylvania, No. 1, logically identified with the Potsdam sandstone of northern New York, makes its appearance along the edges of the limestone No. II at the north foot of the Azoic mountain range between Bethlehem and Reading, in Lehigh and Berks counties; in Mulbaugh Hill, on the Lebanon county line; in Chicques ["Chickis" of Frazer] Ridge, on the Susquehanna, above Columbia; in the Welsh Mountain, in northern Chester; and in the North Valley Hill, which stretches for 60 miles from the heart of Lancaster to the Bucks-Montgomery county line, north of the city of Philadelphia. Its only fossil as yet discovered is a Scolithus, but its position next beneath the Calciferous limestone is too well marked to admit of doubt. Formerly it entirely covered the mountain districts north and south of the Schuylkill River, because it still spreads in sheets upon their sides, and in many places makes their summits, lying unconformably upon the gneiss.

The South Mountains proper, which separate Cumberland from York and Franklin from Adams County, do not thus exhibit the fundamental gneiss covered by a coating of Potsdam, but are composed of peculiar sandstone and slate strata several thousand feet thick, which occupy the place of the Potsdam in the series, but can not certainly be identified with it. They may be considered the equivalents of the Ocoee and Sewanee strata of East Tennessee. * * * We may consider our South Mountain rocks, therefore, those lying north of the turnpike fault, as of Cambrian age.[2]

[1] The object of this paper is to place on record certain observations made during the summers of 1892 and 1893. These observations embraced the belt of Lower Paleozoic rocks lying between the Delaware and Susquehanna rivers and the Potomac River.

[2] A geological hand atlas of the sixty-seven counties of Pennsylvania embodying the results of the field work of the survey from 1874 to 1884: Second Geol. Surv. Penn., Report of Progress X, 1885, pp. xvi, xvii.

The Primal Quartzite is correlated with the Potsdam sandstone of New York in Lehigh and Northampton counties, and is described by Mr. Frederick Prime, jr., as "a hard, compact quartzite, of a yellowish color where weathered, and, when freshly quarried, of a grayish tint. * * * The thickness, where it could be measured, was 21 feet."[1]

The quartzite varies in thickness from 20 to 300 feet, the greater thickness being in the Chickies[2] section of Lancaster County, where, according to Dr. Persifor Frazer, it reaches 300 feet. Southwest of the Susquehanna River it is difficult to measure its exact thickness, owing to complications resulting from faulting and folding and the absence of clearly exposed sections. The character of the formation throughout the State is quite uniform, and the only traces of organic remains that had been found previous to my investigations were the straight, vertical tubes of Scolithus.

In a summary of the Cambrian rocks of Pennsylvania which I published in 1891, occurs the following:[3]

Prof. H. D. Rogers referred a series of slates between the sandstone called Potsdam and the base of the superjacent limestone to the Primal period, but the geologists of the Second Geological Survey consider them as belonging to the limestone series. If a comparison be made with the Tennessee sections, where the schists and shales between the quartzite and the limestone are characterized by Cambrian fossils, this series of schists will certainly be referred to the Cambrian, as it is subjacent to the great limestone series and superjacent to the quartzite. Professor Rogers described the highest of the Primal newer slate as a "greenish and bluish talcose argillaceous slate, sometimes very soft and shaly, and with a thickness of about 700 feet." Dr. Frazer refers about 1,600 feet of "Hydromica-schist" to the interval between the quartzite and limestone in York County.[4]

The upper part of the Primal slates does not appear to be developed to the northeastward in Lehigh, Northampton, Bucks, Montgomery, Berks, and Chester counties. It first appears with any considerable thickness in Lancaster County, near the Susquehanna River, and south of the quartzites of the Chickis Hills. Thence it extends southwesterly across York and Adams counties to the Maryland line, increasing in thickness in Maryland and Virginia.

As a whole, the Cambrian system in Pennsylvania appears to be represented by the lower quartzite and the superjacent shales and schists as originally defined by Professor Rogers, and it may be that the lower portion of the superjacent limestone will be included.

In a letter from Professor Lesley, dated May 8, 1890, he says:

"Reading Ells's paper and Brainerd and Seely's paper in Bull. Geol. Soc. America, just published, with your remarks at the meeting, I naturally reverted to my South Mountain surveys (twenty years ago) east of Chambersburg, Pa. (Fulton and Adams counties), and the strange and powerful impression made on me then by the outcrop of a low ridge of purple shales running from the pike southward, just back (east) of the western mountain ridge. I never saw anything like them, and feel strongly inclined to consider them the Sillery purple shales (Cambrian) of the North. I can not find or remember any description of this outcrop by Frazer. It lies in Fulton County, outside the Adams County line."

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[1] Geology of Lehigh and Northampton counties: Second Geol. Surv. Penn. D^3, Vol. I, 1883, p. 205.

[2] This is the spelling adopted by the United States Board on Geographic Names.

[3] Bull. U. S. Geol. Surv. No. 81, 1891, p. 289.

[4] General notes—Sketch on the Geology of York County, Pa.: Am. Philosoph. Soc., Proc., Vol. XXIII, 1886, p. 401.

In his report on the Geology of Pennsylvania,[1] Professor Lesley summarizes his opinion upon the geology of the South Mountains and Formation No. 1. In this, Formation No. 1 is referred to the Upper Cambrian, and a detailed description is given of its occurrence along the South Mountains and across the State to the Delaware. The superjacent limestone, No. 2, is referred to the Ordovician.[2] Fuller reference will be made to Professor Lesley's descriptions in speaking of the rocks of York County.

During the summer of 1892 I made an examination of the Cambrian rocks between the Susquehanna and the Potomac, and during the field season of 1893 followed it by a rapid reconnaissance of a portion of the area between the Susquehanna and the Delaware, for the purpose of determining whether the lower quartzites with their superjacent limestones were of the same geologic age as the quartzites southwest of the Susquehanna. When I took up the work, after an examination of the published literature, including geologic sections and maps, I decided to begin the investigation in York County, along the Susquehanna, as the section there and about the Hellam Hills appeared to be less disturbed and to present more favorable conditions for obtaining good results than the area to the southwest.

YORK COUNTY.

On the map of the First Geological Survey of Pennsylvania[3] the area now under consideration in York County was included under the colors of the "Primal sandstone" (Potsdam) and the Auroral limestone, the latter being equivalent to the Black River-Chazy limestone and Calciferous sand-rock of the New York section, as explained in the key to the geological map.

During the progress of the Second Survey Dr. Persifor Frazer, jr., was placed in charge of the survey of York and Adams counties. On his map of York County, published in 1879, the formations under consideration are subdivided more than on the Rogers map of 1858. They are bounded on the north by the Mesozoic "New Red" sandstones, and on the southeast by "Azoic slates, etc.," and consist, in descending order, according to the legend, of—

4. Limestone (Silurio-Cambrian?).
3. Hydromica-schists, etc.
2. Quartzite (Potsdam?).
1. Chlorite schists, etc.

In the report of progress for 1874–75, Dr. Frazer states that the schists (3) carrying the iron ore do not belong to the Auroral limestones, but to a series of schists beneath, and that there is, probably,

[1] A Summary Description of the Geology of Pennsylvania, Vol. I, 1892, chapters 15 and 16.
[2] Loc. cit., p. 307.
[3] Henry D. Rogers, 1858.

a line of unconformity between the limestones and the subjacent "Crystalline schists."[1]

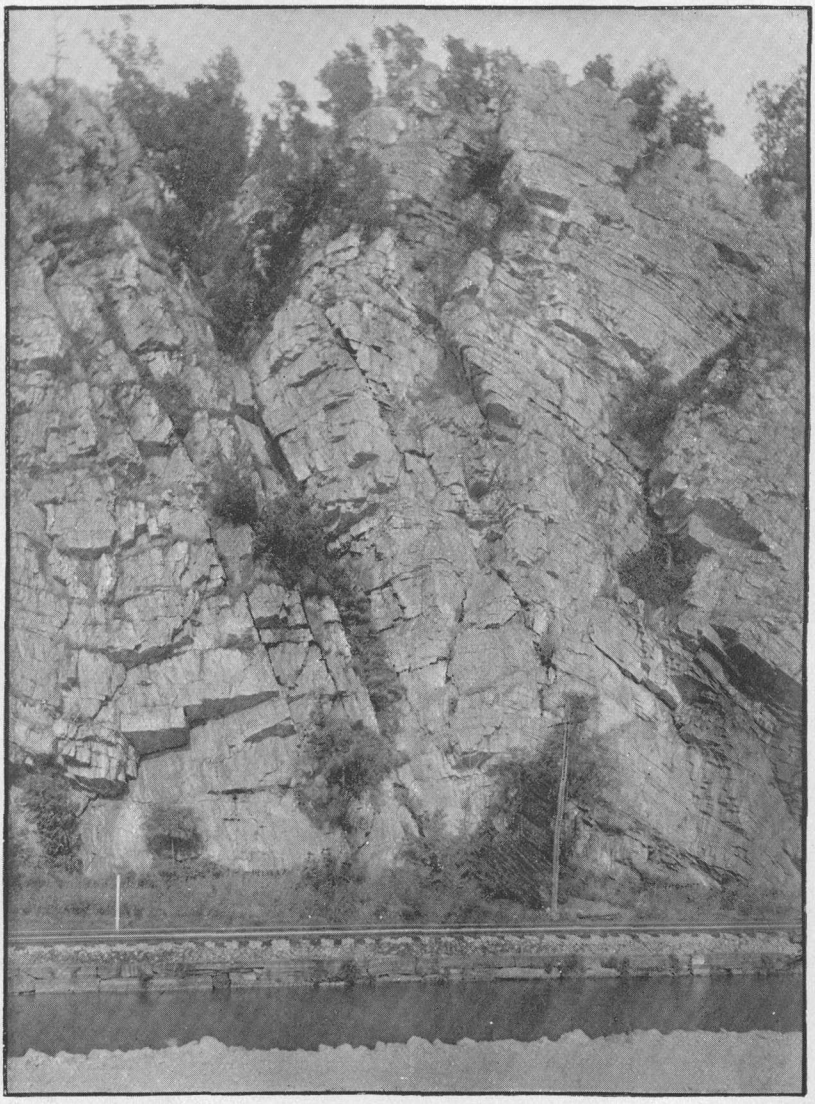
In discussing the question of the contemporaneity of the schists with the limestones called by Dr. Rogers the "Auroral," he concludes that two questions are involved: "First, are two limestones of different ages confounded under the name of 'Auroral;' second, if so, are they conformable the one to the other?" He decided that the crystalline schists containing the ore bodies seem to form the floor on which the York limestone lies, while another limestone seems to be bedded with them.[2] Mention is also made of a limestone conglomerate consisting of a blue limestone holding rounded pebbles of white limestone within it, that occurs in a quarry half a mile north of the Columbia Bridge.[3]

The preceding is quoted to show that Dr. Frazer had a conception that there is a limestone beneath the York limestone, embedded in the unconformably subjacent schists, that is not of the same age as the "Auroral" limestones, which were referred to the Chazy-Calciferous horizon by Rogers and others. The evidence for this is materially weakened by the statements contained in his report on Lancaster County, that the Lancaster limestone—

> * * * has great masses of hydro-mica schists, argillites, rhomboidal slates, and gray, weathered, leached-out pyritiferous strata. * * * Slates and argillites, and, perhaps a little more rarely, true hydro-mica rocks may come into any horizon of the limestone. * * * This intercalation of foreign beds does not seem to be at present reducible to any rule, though in general such transitions seem to be more frequent in the lower than in any other parts of the measures.[4]

He considers the Lancaster limestones as probably the equivalent of the Calciferous and Trenton limestones of the New York series, and mentions that the York limestone is a slender offshoot.[5] The Hellam quartzite of York is called the "Chikis" quartzite, and is described as a basal formation upon which a series of schists occur that to the south "are, at all events, those slates in which the iron ores of Lancaster and York are invariably found—the transition series between the 'Primal and Auroral.'"[6] In his final report,[7] Professor Lesley describes the "Chiques" sandstone as the same formation as the Hellam quartzite of York County (as named by Frazer) and equivalent to the Upper Cambrian quartzite of Walcott. He prefers to use the older name "Chiques" for these sandstones, stating that it is best to get rid of the old name "Potsdam" sandstone, as there does not seem to be any satisfactory evidence that the proper Potsdam sandstones of the Canada line and Lake Champlain extend as far south as southern

[1] Second Geol. Surv. Penn., Report of Progress in the District of York and Adams counties, 1876, p. 130.
[2] Loc. cit., pp. 132, 134.
[3] Loc. cit., p. 132.
[4] Second Geol. Surv. Penn., Report of Progress in 1877, Geol. of Lancaster County, 1880, p. 5.
[5] Loc. cit., p. 4.
[6] Loc. cit., p. 7.
[7] Geol. Surv. Penn., Summary Description of the Geology of Pennsylvania, Vol. I, 1892, p. 165.



CENTRAL PORTION OF THE CHICKIES QUARTZITE AT CHICKIES ROCK, ON THE SUSQUEHANNA RIVER, LANCASTER COUNTY, PENNSYLVANIA.

Pennsylvania. He says that the section at "Chiques Rock" is not quite comprehensible at one or two points. I found that it is so complicated by the folding of the strata and by thrust-faulting that it is not a typical section. It exposes, however, the lowest of the Cambrian now known to me in central Pennsylvania. The quartzite at "Chiques Rock," near Chickies, is the Scolithus quartzite, and is stratigraphically at the summit of the series of quartzites and slates forming the "Chiques Rock" section, although apparently at the base in the section, owing to the disturbance of the strata. The quartzites and slates to the south, between "Chiques Rock" and the limestones at Columbia, are older, and have been raised up from beneath and thrust over on the Scolithus quartzite at "Chiques Rock." This is determined by the succession shown in the section exposed on the flanks of South Mountain, in Franklin County, west of Monterey, reference to which is made in the notes on the geology of South Mountain.

In relation to the stratigraphic position of the slates, etc., beneath the Lancaster limestone, I will quote the statement of Professor Lesley:

> The geographical proof that the slates overlie the quartzite is complete, and establishes the correctness of Professor Rogers's "Upper Primal slate formation." The geological evidence is equally conclusive; for the general dip of the Chiques rock is southward, under the slates; and of the slates southward under the limestone.[1]

The exposure of the Chickies Quartzite at Chickies Rock, on the Susquehanna, is remarkably fine. It rises in a bold bluff 100 feet or more in height, forming a low anticline with a slight synclinal depression near the center. Nearly vertical cleavage planes extend from top to bottom through many of the layers in the central portion. This is shown in Pl. II.

The continuation of "Chiques Rock" to the westward, in York County, forms the Hellam Hills,[2] and shows a broad anticline of quartzite surrounded by schists. Numerous sections along the southern and western sides of the Hellam Hills show that the quartzites pass beneath a series of shales, slates, and sandy and calcareous layers, which, in turn, pass beneath the limestones of the valley.

It was my good fortune to have the acquaintance of Prof. A. Wanner, superintendent of public schools at York. He volunteered to be my guide to localities where he knew there were good exposures of the quartzites, schists, and limestones; and he accompanied me for a week.

The study of the rocks in York County was begun under the impression that the limestone was the "Auroral" limestone of Rogers, and equivalent to the Chazy-Calciferous of the New York section. I thought, however, that there was a probability of its being Cambrian in age, from the fact that in Tennessee, Vermont, and New Jersey the lower

[1] Loc. cit., p. 172.

[2] I did not learn, when in York County, of any local name for this ridge of hills, and as most of the ridge is within the township of Hellam I shall speak of them as the Hellam Hills.

portion of the great limestone series above the quartzite and shales, is undoubtedly of Cambrian age.

A reconnaissance was first made of the section at "Chiques Rock," thence south to Columbia, Pa., and then on the western side of the river from Wrightsville north to the quartzites. A careful study of the "Chiques Rock" section led me to think that there was a considerable disturbance and a complication of the normal section, by overthrust of the lower beds upon the higher, between the Scolithus quartzite at "Chiques Rock" and the limestone at Columbia. On the western side of the river the section appeared to be unbroken from the Hellam Hills to Wrightsville, and to be as represented by Dr. Frazer in his section along the right bank of the Susquehanna.[1] In this the succession is from the quartzite (1) to the shales (2) and to the limestone (3), in Wrightsville, at Columbia Bridge. The sandy shales and argillites (2) pass conformably beneath the massive limestone (3), which forms a deep synclinal fold before being cut off to the south by a fault.

The second section examined was No. 2 of Dr. Frazer's, extending from Emigsville south through Red Lyon Station.[2] In the description of this section[3] he refers the sandstone in the railroad cut just north of Emigsville to the Triassic New Red sandstone. At the northern end of the cut he noted a fine-grained sandstone dipping W. 15°, N. 52°. To the southward of this he describes a calcareous, sandy, pink shale dipping S. 5°, E. 20°. This is subjacent to 27 feet of blue, finely laminated limestone, with white streaks, upon which rests a red bed of calcareous conglomerate 2 feet thick; this, in turn, is subjacent to a belt of reddish, shaly sandstone, 63 feet in breadth, and a compact, fine-grained sandstone, 9 feet in thickness, which is capped by 156 feet of arenaceous shales of a somewhat flaggy character.

Dr. Frazer says:

> There would seem to be, therefore, an anticlinal in the Triassic measures—the only instance of one recorded within the limits of this district. The contact line of limestone and Mesozoic sandstone lies within or just north of the town of Emigsville. The first recorded dip in the older formation when projected upon the line of section is 2,160 feet, or a little more than a third of a mile from the last dip.[4]

I mention the details of Dr. Frazer's section because it is the one which led to the determination of the stratigraphic position of the Chickies quartzites and the York shales,[5] which are subjacent to the

[1] Second Geol. Surv. Penn., 1876; section 1 accompanying Report of Progress in the district of York and Adams counties for 1874.

[2] Loc. cit., section 2.

[3] Loc. cit., p. 88.

[4] Loc. cit., p. 89.

[5] The name "York shales" is proposed for the band of shales resting upon the quartzites surrounding the Hellam Hills. It is particularly well developed in York County, but appears to be absent in many of the sections about South Mountain and about the same series of quartzites in Lancaster County.

Lancaster limestone.[1] The fault between the Paleozoic (Lower Cambrian) rocks and the New Red sandstone of the Mesozoic occurs in the railroad cut at the point indicated in Dr. Frazer's section as the crest of an anticline in the New Red sandstone. No such anticline exists. The southern leg of Dr. Frazer's anticline is formed of rocks that bear no resemblance to the Mesozoic Red sandstone, and fossils of Lower Cambrian age are abundant in the 9 feet of compact, fine-grained sandstone described by him. The section, from the fault line southward, is as follows:

Section from Emigsville south through Red Lyon Station, Pa. Thickness in feet.

1. Gray, banded, and mottled limestones, with purplish bed of limestone at summit 3 feet thick. Strike, E. and W. (mag.); dip, 25° S. This limestone weathers into a more or less arenaceous shale..... 33
2. Gray and buff sandy shales passing (at 21 feet) into shaly sandstone and then into sandy shale, where a belt of calcareous quartzite occurs in layers varying in thickness from 2 to 12 inches. Fossils: *Camarella minor*, and fragments of Olenellus showing portions of the head and thoracic segments[2] 105
3. From the fossiliferous beds just mentioned, for a distance of 500 feet, the hillside on the east side of the railroad is covered with the débris of sandy shales, and several exposures occur along the roadside. From the last of these to the first outcrop of limestone, a distance of 250 feet, the débris of sandy shales and thin-bedded calcareous quartzite occur abundantly in the southward-facing hill slope. Fossils: Numerous fragments of Olenellus and casts of *Camarella minor* occur in the calcareous quartzite interbedded in the shale. As the last observed dip was 25° S., it is assumed that the section is unbroken, and a thickness is assigned to this division of..... 315
4. Massive-bedded, dove-colored, banded limestones. Strike, N. 20° W. (mag.); dip, 25° S.[3] Although the section is more or less concealed by soil, numerous outcrops occur in quarries to the south. These show a banded limestone in the lower portion of the section, with numerous irregular, small, concretionary bits of limestone, usually elongated with the bedding plane. The average dip of the bed is from 20° to 25° S.° A beautiful section is shown in a quarry about one-fourth of a mile east of Emigsville, and in a quarry on the turnpike west of the railroad, in the outskirts of the town. A little higher up in the section the limestones are massive, light-colored, and, in places, almost a crystalline marble.

   At a quarry in a field east of the railroad track and near where the road turns to the eastward toward Codorus Creek, the strike of the limestone is N. 15° W. (mag.), and the dip 15° S. One of the layers is quite fossiliferous and gave fine specimens of *Iphidea bella*, *Salterella conica* n. sp., *Protypus senectus*, heads of small trilobites of the genera Solenopleura and Zacanthoides, and numerous fragments of the head and thoracic segments of a species of Olenellus.

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[1] The term "York limestone" was proposed by Dr. Frazer for this limestone; but, as he states that it is a prolongation of the Lancaster limestone into York County, and that it is more fully developed in Lancaster County, I think it best to retain the term Lancaster limestone, as it is hardly necessary to call the same limestone by different names in adjoining counties.

[2] On the line of strike of these beds, 2 miles northwest of Emigsville, the following fauna was found in the calcareous sandstones: *Camarella minor*, *Obolella crassa (?)*, *Hyolithes communis*, and fragments of Olenellus.

[3] Dr. Frazer's section indicates a dip of 85°. I was not able to discover the locality where it occurred.

Section from Emigsville south through Red Lyon Station, Pa.—Cont'd. Thickness in feet.

Farther to the westward, in an old quarry east of the Northern Central Railroad track, massive layers of limestone are shown that have a strike N. 20° W. (mag.), dip 20° S., and contain fragments of the genera Olenellus and Protypus. The next higher exposure in that section is in a large, deep quarry just west of the railroad track, between one-fourth and one-half mile south of Emigsville. About 60 feet of limestone is exposed. The strike is E. and W. (mag.), with a dip of 10° S. In the lower portion of the quarry massive layers of arenaceous limestone occur, and about 10 feet from the summit of the section are alternating bands of earthy and pure limestone in which numerous fossils occur. In the collection obtained I have recognized plates of Cystids, Kutorgina n. sp., *Billingsella festinata* Billings, Olenellus (fragments), and *Protypus senectus* Billings. The fragments of Olenellus indicate individuals as large as any known. The fossils range through about 20 to 25 feet of the limestone.[1] The layers above the fossiliferous band are largely brecciated and form a limestone conglomerate.

In the railroad cut the limestone is shown, and a little to the north of it cleaved slates, the bedding of which strikes east and west (mag.), and dips 10° S. There is an interval of 20 feet between the limestone and slates covered by debris. The limestone appears to pass beneath the slates, and from the areal distribution of the slates and limestone to the south and southwest it is probable that this upper band of slates has a wide distribution. Its thickness is unknown.

Estimated thickness of the entire series of limestone 750

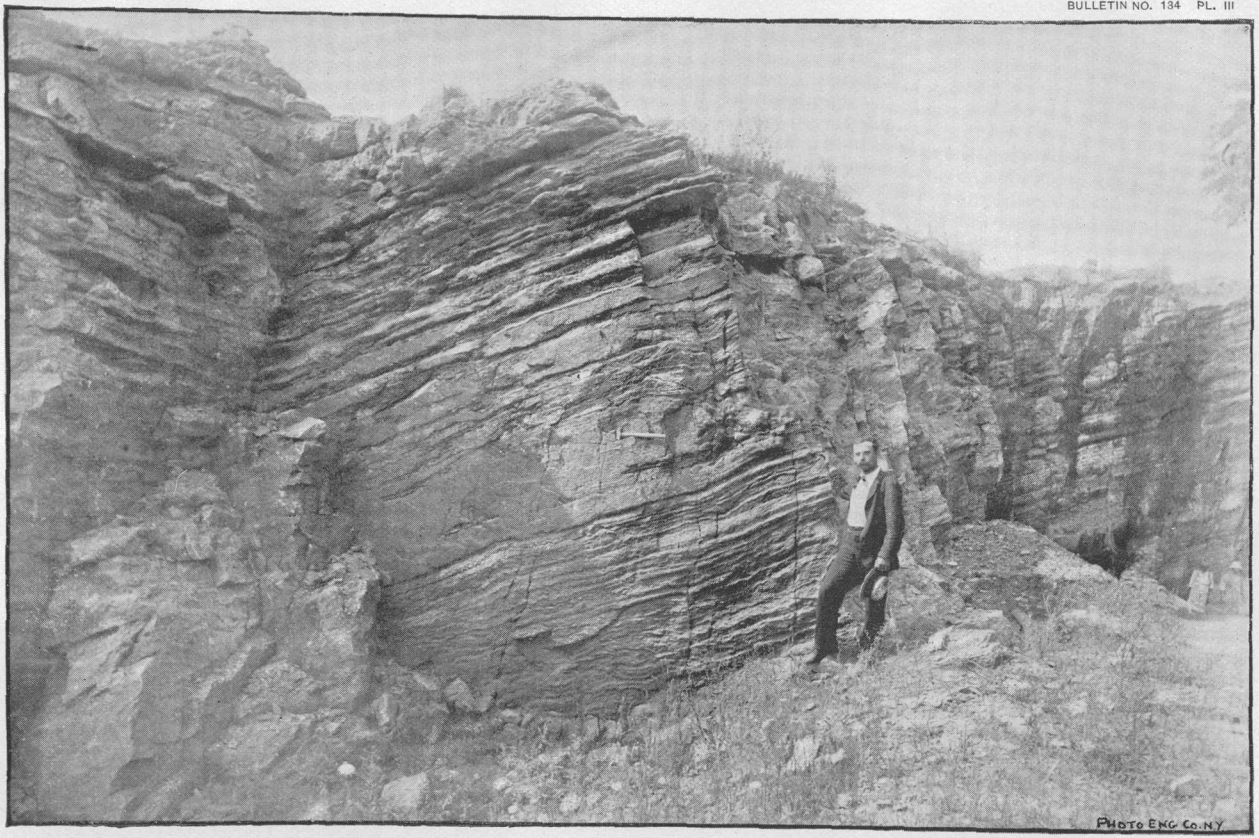
The banded limestone of No. 4 is beautifully shown in a quarry about one-fourth of a mile southeast of Emigsville. This is exhibited in Pl. III, where the more siliceous layers are brought out in strong relief by the solution of the purer limestone layers.

On the geological map of York County an area of the Hellam quartzite is indicated 2 miles northwest of Emigsville. We found this to be a continuation of the calcareous Olenellus quartzites beneath the limestone of the section at Emigsville. They form a narrow, continuous belt, and were traced northwestward nearly over to New Holland, on the Susquehanna.

A section from a point 1 mile east of Emigsville to the limestone north of New Holland shows an anticlinal structure with the Olenellus quartzite at the center of the anticline, and above, in turn, the shales and limestones. This quartzite is colored on the map as of the same age as the Hellam quartzite. It is, as we now know, a thinner belt of quartzite resting in the calcareous and sandy shales above the quartzite of the Hellam Hills.

The next point determined was the actual relation of the Olenellus quartzite at Emigsville to the massive Scolithus quartzite of the Hellam

[1] At a locality 4 miles north of York, on the left bank of Codorus Creek, and one-eighth of a mile below Meyers's mill, near Emigsville, Prof. A. Wanner and Mr. Charles Schuchert found the following species *Eocystites* ——, *Iphidea bella* Billings, two undescribed brachiopods, *Billingsella festinata* Billings *Hyolithes americanus* Billings, *Salterella conica* n. sp., *Protypus senectus* Billings, *Olenellus thompsoni* Hall (?). This fauna is a characteristic middle Olenellus-zone fauna, and may be compared to that of the upper Winooski marble of the Vermont section. They also found, south of Eisenhardt's schoolhouse, on Liverpool road, 3 miles northwest of York, *Billingsella festinata* Billings, *Hyolithes americanus* Billings, *Salterella conica* n. sp., and *Olenellus thompsoni* Hall (?).



BANDED LOWER CAMBRIAN ROCKS ONE-FOURTH MILE SOUTHWEST OF EMIGSVILLE, YORK COUNTY, PENNSYLVANIA.

Hills. In passing from Pleasureville toward York, on the steep side-hill 2 miles west of York, there are, in the roadside, exposures of the shales and calcareous sandstone above the massive quartzite of the Hellam Hills. At a point probably 100 feet beneath the ferriferous shale in which the numerous ore pits occur, on the south side of the Hellam Hills, a species of Obolella, very closely allied to *Obolella crassa*, and fragments of Olenellus were found in the decomposed calcareous sandstone. At a locality about 1 mile south of Mount Zion church, in Hellam Township, and 4 miles northwest of York, numerous specimens of *Camarella minor* and fragments of Olenellus occur in a calcareous quartzite identical in character with that of the Emigsville section. These two localities prove that the Scolithus quartzites of the Hellam Hills and of "Chiques Rock" are beneath the Olenellus calcareous quartzites of the Emigsville section, and are therefore of Lower Cambrian age.

Search was next made for fossils near the base of the limestone above the ferriferous shales resting on the quartzites of the Hellam Hills. They were found a short distance above the shales in a small quarry of thin-bedded limestone by the roadside, $1\frac{1}{8}$ miles north of Stoners Station, on the York and Wrightsville Railway. The strike is a little north of west, and the dip 45° S. Finely preserved specimens of Linnarssonia, closely allied to *Linnarssonia sagittalis*, are abundant, and easily recognized fragments of a species of Olenellus are associated with them. Crossing the section to the south, occasional exposures were seen of massive-bedded, light-colored limestones of much the same character as those exposed in the quarries north of Wrightsville, 3 miles to the eastward. The dip increased to 85° at the railroad track, which indicated that a compressed syncline had been passed over in the section.

Fine exposures of the massive and more finely bedded limestones are shown in the quarries in the suburbs of York. Where the soil has been recently removed the characteristic erosion by solution is frequently seen. This is exhibited in Pl. IV, where the white limestone looks very much like the hummock ice of an ice floe. Pl. V is an illustration of one of the minor folds in the more finely bedded limestone. This is above the more massive limestones shown in Pls. IV and XI. The massive limestones of Pls. IV and XI are correlated, although in Pl. XI the rock is seen to carry a limestone conglomerate.

Through the efforts of Prof. A. Wanner, the fauna of the main body of the limestone in York County has been largely increased since my visit. Mr. Charles Schuchert also made a collection at Professor Wanner's localities. A study of all the material gives the following lists of species:

Fossils from Cutcamp's quarry, north of Cottage Hill, York, Pa.

Cystidian plates.
Microdiscus, like *M. parkeri* Walcott.
Olenellus sp. undet.
Zacanthoides sp.?
Ptychoparia adamsi Bill.
Ptychoparia teucer Bill.
Agraulos sp.?

The fauna is strongly marked by the presence of the two undetermined species of Zacanthoides and Agraulos. It is essentially of an upper Olenellus-zone type.

Fossils from roadside north of Highland Park, York, Pa.

Olenoides like *O. marcoui* Whitfield.
Protypus senectus Bill.
Ptychoparia.

A fauna similar to this occurs at the upper limit of the Olenellus zone in the Parker section of Georgia, Vt. The absence of Olenellus is unusual, as that genus is almost always present in all Lower Cambrian rocks; and it may be a fair inference to consider the horizon at which these fossils occur as beds of passage between the Lower and the Middle Cambrian.

Fossils from cellar diggings, corner Penn and North streets, York, Pa.

Sponge undet.
Eocystites.
Acrotreta sp.?
Agnostus sp.?
Zacanthoides sp. undet.
Bathyuriscus sp. undet.
Ptychoparia sp. undet.
Ptychoparia sp. undet.

This fauna is to be referred to the lower horizon of the Middle Cambrian. It is marked by a very characteristic form of Agnostus and Bathyuriscus.

When examining the section on the east side of the Susquehanna, in Lancaster County, south of Columbia and north of Washington Manor, with Messrs. A. Wanner and Arthur Keith, we found a locality of Lower Cambrian fossils in a narrow belt of limestone about half a mile north of Washington Manor. In the material collected *Hyolithes communis* and fragments of Olenellus showing portions of the head and thoracic segments were recognized.

A glance at Dr. Frazer's map of York County shows that, in all probability, all of the limestones, quartzites, and schists of the central portion of the county are of Cambrian age. The Hellam quartzite ridge is, as stated by Dr. Frazer, evidently an anticlinal ridge, broken in the northwest side by a fault that has brought the quartzites up against the higher horizons of the shales and limestones. The anticlinal structure apparently extends to the southwest, past York and toward Hanover.

The discovery of Lower Cambrian fossils in the compressed syncline of limestone in Lancaster County, south of Columbia, indicates that the limestone on the west side of the river is of the same geologic age, and that the shales and schists beneath it (called chlorite-schists, etc., by Frazer) are of Lower Cambrian age; and I doubt if there is in York County a sedimentary rock—other than the Mesozoic New Red sandstone—of later age than the Cambrian, unless it be the Peach Bottom slate and chlorite-schists of the southeastern corner of the county; and from the closely related structure of Lancaster County it is very

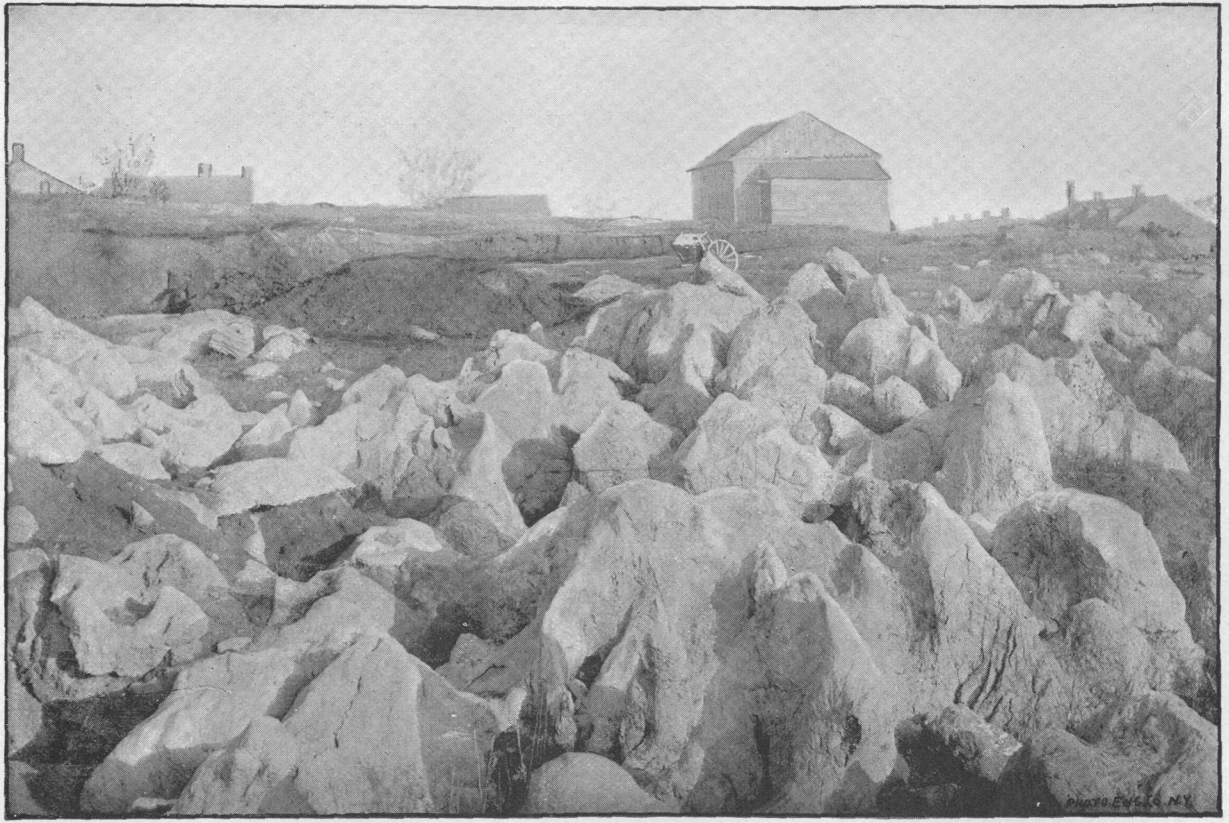


ILLUSTRATION OF EROSION BY SOLUTION BENEATH THE SOIL OF A MASSIVE BED OF LOWER CAMBRIAN LIMESTONE, EXPOSED IN A LIMESTONE QUARRY ON THE EAST SIDE OF YORK, PENNSYLVANIA, WITHIN THE CITY LIMITS.

probable that all the Lancaster limestones will fall within the Cambrian, unless it be some portions of the upper series of limestone, which may pass into the Ordovician. This generalization will also apply to the limestones of the adjoining counties of Berks and Chester, and, in fact, to the entire extension of this series northeastward to the Delaware. All of the quartzites that have been referred to the Potsdam will necessarily fall into the Lower Cambrian, as they are beneath the limestones.

When it is borne in mind that the quartzites that have been called the Potsdam by the Pennsylvania Survey are of Lower Cambrian age, that a series of schists and limestones superjacent to these are of Lower Cambrian age, that the Potsdam horizon of the New York series is represented by limestones in the Auroral series of Rogers, and that the Calciferous-Chazy terrane of the New York section is represented only by the upper portion of the Auroral limestones, geologists will have little difficulty in determining the geologic horizons of the various outcrops of quartzites, schists, shales, and limestones, provided careful attention is paid to their sedimentary character and to the discovery of occasional localities of fossils.

SOUTH MOUNTAIN.

Professor Lesley states that—

> The South Mountains, separating the Cumberland Valley from the lower country of York and Adams county, are the northernmost end of the Blue Ridge range of Virginia. * * * The whole measures upon the map 10 miles in breadth by 50 in length, upon a curve extending from the Maryland line to its northeastern end, 15 miles west of Harrisburg.[1]

From the Pennsylvania line southwest across Maryland, South Mountain extends, as the Blue Ridge, to Harpers Ferry, and thence southwest across Virginia. It practically includes, also, the Catoctin range, on the eastern side, which extends south from the southwestern portion of Adams County, Pa., and crosses the Potomac at Point of Rocks, and thence extends south a little west of Leesburg, Va. The Blue Ridge and the Catoctin Ridge are the eastern and western sides of the mountain uplifts of which South Mountain, Pennsylvania, is the northern terminus. Prof. H. D. Rogers describes South Mountain as composed almost entirely of rocks of the "Primal series." He says:

> It is doubtful if the true gneissic rocks anywhere reach the surface within its borders, and only in one or two localities have even the lowest members of these Auroral limestones been met with covering the upper Primal slates. Even of intrusive igneous rocks it embraces a singularly small amount, those met with being chiefly greenstone and trap rock.[2]

On the geologic map accompanying this report the South Mountain area is indicated as unaltered Primal rock. He regarded the quartzite of South Mountain as the Primal quartzite, and the shales as the Primal

[1] Second Geol. Surv. Penn., A Summary Description of the Geology of Penn., Vol. I, 1892, p. 142.
[2] The Geology of Penn., Vol. I, 1858, p. 203.

slates, and mentions that at one locality, Pine Grove Furnace, there occurs in the middle of this range of slate a narrow band of limestone, marking the position of the axis or keel of the trough into which the formations have been folded.[1] He speaks of a band of altered siliceous rock, and south of it a zone of green altered slate charged with epidote; overlying this again, another belt of a more siliceous altered slate.[2] In speaking of the lower Primal slates beneath the quartzites, he says:

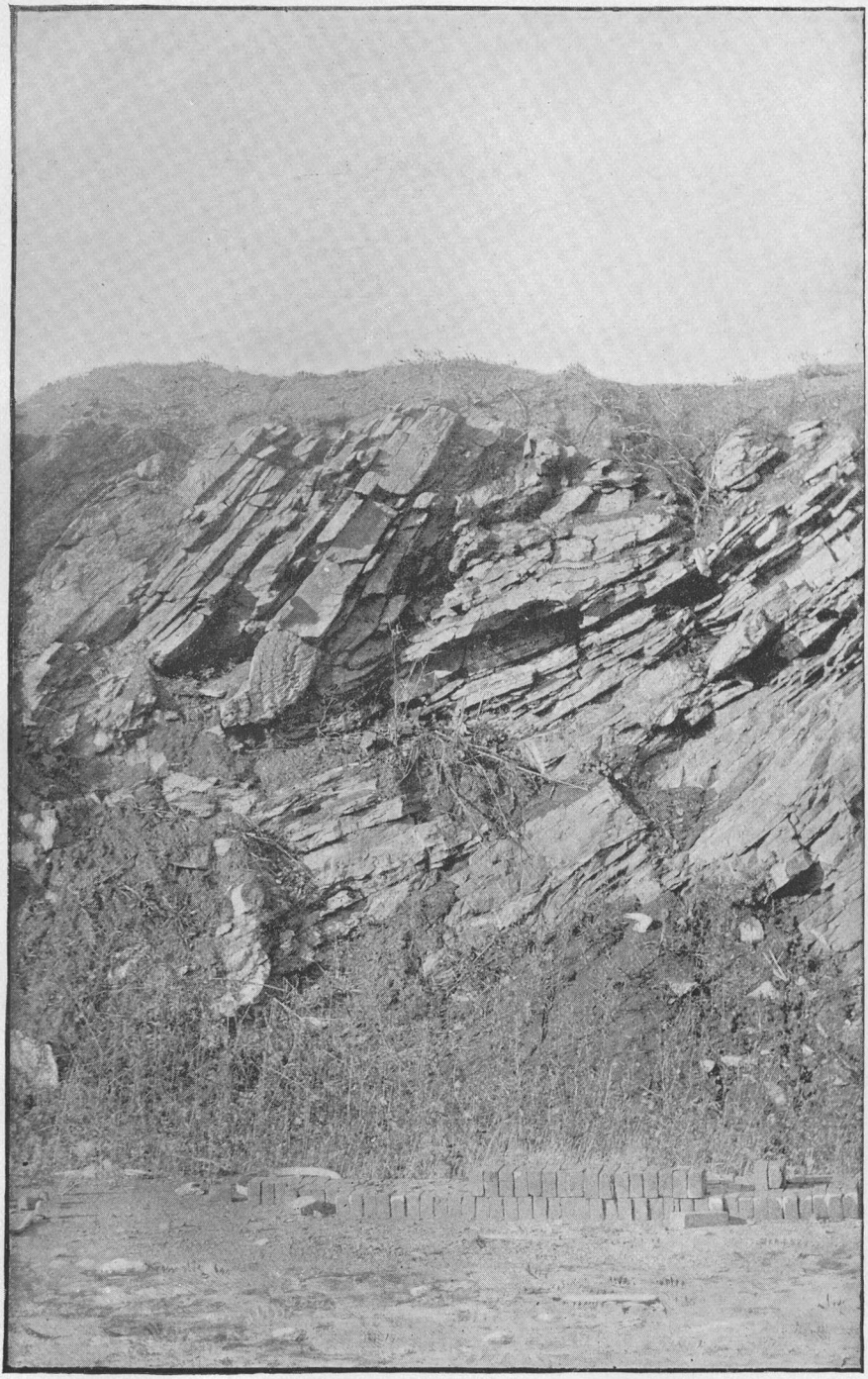
> These lower Primal slates are highly indurated, and even decidedly crystalline, containing in some of their layers segregated specks and even half-formed geodes of epidote and other minerals. They bear a strong general resemblance to the half crystallized, older Primal slates just south of Spring Mill. * * * Near the tunnel at the northwest side of Jacks Mountain there is a hard epidote rock, and not far from it highly altered greenish slate—a rock found in several other localities farther west, and containing layers of grey slate spotted with epidote. Farther west occurs epidote with asbestos.[3]

Of the metamorphic strata of Pennsylvania, Prof. H. D. Rogers says that before the geological surveys of Pennsylvania and Virginia were organized the ancient and more altered strata between the summit of the Atlantic Slope, in the Blue Ridge and South Mountain, and its base at the margin of tide water were regarded and designated alike as primary rocks, and were supposed to constitute but one group—the oldest known to geologists:

> Early, however, in the course of those surveys, it came to light that by far the larger portion of the rocky masses of at least the middle and northwestern tracks, including much of the Blue Ridge and of the Green Mountains, were of a different type and age from the oldest metamorphic or true gneissic system. The evidence in support of this conclusion was, first, an obvious and very general difference in the composition of the two sets of strata; secondly, a marked difference in their conditions of metamorphism; and thirdly, and more especially, a striking contrast in the direction and manner of their uplift.[4]

He regarded the sandstone with *Scolithus linearis* as at the base of the Paleozoic series, and believed that the Primal slates beneath the sandstone, and in intimate alternation with it, did not possess a vestige of organic life. He then states that there are now two main horizons subdividing the more or less metamorphic strata of the Atlantic Slope into three systems of groups—the one, a physical break or interruption in the original deposition of the masses; the other, a life limit or plane denoting the first advent, so far as yet discovered, of organic beings. These two planes are not coincident, but include between them a thick group of sedimentary rocks, separated from the lower physically, from the other paleontologically. To the most ancient or lowest group he gave the name of the Gneissic series; to the great middle group, less crystalline than the gneissic, and yet destitute of fossils, the descriptive terms Semimetamorphic or Azoic; and to the third or uppermost system—the entire succession of the American Appalachian strata, from the Primal to the true coal rocks—the term Paleozoic. As summed up, this classification is: The Hypozoic rocks, or those underneath any life-bearing strata; Azoic, or those destitute of any discovered relics of life;

[1] Loc. cit., p. 203. [2] Loc. cit., p. 205. [3] Loc. cit., p. 207. [4] Loc. cit., pp. 62, 63.



SYNCLINAL FOLD IN THE THIN-BEDDED LOWER CAMBRIAN LIMESTONES, AS SEEN IN A QUARRY IN THE SUBURBS OF YORK, PENNSYLVANIA.

and Paleozoic, or those entombing the remains of the earth's most ancient forms of living beings.[1]

It is evident from Professor Rogers's definition of the Azoic group that it included what we now recognize as the Lower Cambrian sedimentary strata beneath the Scolithus quartzite, and also an extended series of altered rocks that form the nucleus of the Blue Ridge and which are now included in the Algonkian of the classification of the United States Geological Survey.

The conclusions of the geologists of the Second Geological Survey of Pennsylvania are that there are two groups of rocks forming South Mountain. Dr. Frazer states:

> Hence, it is made apparent that the great South Mountain chain is composed essentially of two groups of rocks, the lower (and along this line the northwestern) consisting of various modifications of the quartz conglomerate above spoken of, and in which quartzite occurs in various forms. The upper and southeasterly group is felsitic in character, but contains also large beds of hydro-mica and chlorite schists intersected by veins of milk quartz, while the orthofelsite itself presents every variety of appearance, from a sandy and earthy slate in which the crystals of orthoclase are very much decomposed—indeed are sometimes almost clay—through the jasper-like variety to the massive and coarsely porphyritic structure in which it is suited to be used as an ornamental building stone.[2]

In a paper entitled "The Lake Superior Copper Rocks in Pennsylvania,"[3] Mr. J. F. Blandy gives a figure of an ideal section of South Mountain in which the sandstones pass beneath the epidote traps, etc. In the discussion following the reading of the paper (at a subsequent session) Dr. Frazer states that "the Potsdam or Primal Formation of Rogers is wanting all over that county, with the exception perhaps of detached patches on the northwest flank of the South Mountain chain." He reaffirms his view that the rocks of South Mountain may be divided into two great series: "A western (underlying), of which the characteristic strata are composed of quartzite and of arenaceous schist containing quartz pebbles (Mountain Creek rock), and the eastern (overlying), of hydro-mica and chlorite schists, and orthofelsite, both porphyritic and unporphyritic."[4] At a later date Dr. Frazer[5] explained the structure of the copper belt of this region by the presence of a series of faults, which have brought blocks of strata in different relations to one another, and thus repeated the sections:

> But the great width of the South Mountain chain along the Chambersburg turnpike, the abrupt protrusion to the east of the eastern part of the chain, south of the Chambersburg-Gettysburg turnpike, and of the western part of the chain to the west, north of this line, and the contacts of the Paleozoic and Eozoic rocks of very different horizons in the middle portions of the chain, all point to the existence of extensive longitudinal and transverse faults in these measures.

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[1] Geology of Pennsylvania, Vol. I, 1858, pp. 63, 64.

[2] Second Geol. Surv. Penn., Report of Progress in the counties of York, Adams, Cumberland, and Franklin for 1875 (1877), p. 285.

[3] Trans. Amer. Inst. Mining Eng., Vol. VII, 1879, p. 332.

[4] Loc. cit., p. 338.

[5] An Hypothesis of the Structure of the Copper Belt of the South Mountain: Trans. Amer. Inst. Mining Eng., Vol. XII, 1884, pp. 82–85.

Professor Lesley says:

The northwestern (Mount Holly) ridge is made by several thousand feet of the lower quartzite and quartz conglomerate beds. The southeastern (Adams County) ridges are made by several thousand feet of an overlying feldspathic, micaceous, and chlorite series, intersected by veins of milky quartz.

These two series, or great subdivisions, seem at some places to graduate into each other, as if they were the earlier and later deposits of one age. In other places (as in the Greenwood section No. 10) they seem distinct, the passage from the lower quartzite series to the higher porphyritic (orthofelsite) series being abrupt, with even an apparent difference of strike in some of the outcrops along the line of section.[1]

In a footnote he calls attention to the resemblance of the feldspathic rocks of the upper group of rocks to the kaolin slate beds in the Virginia Blue Ridge section at Balcony Falls, as described by Fontaine.[2] He regards the lower, or quartzite and conglomerate slate, series as certainly immensely thick, and says that a total thickness of 14,000 feet is suggested along Dr. Frazer's cross-section No. 10. Other sections across the mountains toward Mount Holly Springs exhibit a certain minimum thickness of 5,000 feet, and a possible maximum thickness of 10,000 feet and 12,000 feet, of quartzite series.[3] It is further stated that the thickness of the overlying feldspathic felsite series, along the Mount Holly cross-section No. 8 of Dr. Frazer's, exceeds 6,000 feet, as shown in the broad syncline:

The Mountain Creek rock subdivision of the lower series is characterized by scattered pebbles and by occasional solid beds of conglomerate. Dr. Frazer gives it various names, descriptive of its varieties: "Schist conglomerate," "green schist with quartz pebbles" (some of them of transparent quartz, others of amethyst-colored quartz), these last two varieties of conglomerate marking a transition to the Upper series. It is evident that the great Lower series, if indeed it be separable from the Upper, has the lowest set of beds which are almost wholly of metamorphosed sand, quartzite; then higher sets of clay, sand, and pebble beds, metamorphosed into quartzose slates, shales, schists, and pebble rock.

The still higher and more or less magnesian slates, hard shales, crystalline schists with scattered pebbles, conglomerate beds, and porphyritic beds, make an indefinite, but recognizable Upper system, in which occur also true quartzite beds, like those at the bottom of the Lower series. Occasional fragments of diorite trap appear on the surface which may indicate interbedded volcanic rocks, or possibly very small dikes. The whole may have been capped by the Hellam (Chiques rock) quartzite, fragments of which are so abundant on the lower southeast slope of the South Mountain mass. It is hard to avoid the inference that our South Mountain rocks represent the Huronian section of Murray and Logan. It is impossible not to compare them also with the great quartzite masses, the roofing slates, etc., of Walcott's Upper, Middle, and Lower Cambrian system.[4]

Professor Lesley regards the conglomerate beds as fixed horizons in the series, and states that they may be exaggerated in number on account of repetition in anticlinal and synclinal folds.[5]

It will be observed from the preceding views of Professor Lesley's

[1] Second Geol. Surv. Penn., A Summary Description of the Geology of Penn., Vol. I, 1892, pp. 144, 145.

[2] Loc. cit., p. 144.

[3] Loc. cit., p. 145.

[4] Loc. cit., pp. 147, 148.

[5] Loc. cit., p. 150.

that he was in doubt as to whether the South Mountain rocks were of Huronian or Lower Cambrian age.

In speaking of his study of the South Mountain, west of the Susquehanna and stretching southward to the Potomac, Dr. T. Sterry Hunt says of the pre-Paleozoic rocks:

In this portion, so far as I am aware, it shows no Laurentian north of the Potomac, but consists of Montalban and Huronian, the latter constituting the strata at Harpers Ferry and for some miles to the eastward along the Baltimore and Ohio Railroad. In the southern part of Pennsylvania to the west of Gettysburg this mountainous belt, rising between the Mesozoic on the east and the great limestone valley on the west, presents an immense development of a peculiar type of crystalline rocks which I detected there last year and which has a considerable geologic importance. It is a bedded petrosilex, grayish, reddish, or purple in color, sometimes granular, but more often jasper-like in texture, and frequently porphyritic from the presence of small crystals of orthoclase-feldspar or of glassy quartz. There is here found a great breadth of this rock distinctly bedded, presenting different varieties, and alternating with diorite, or diabasic, epidotic, and chloritic rocks, with argillites, in which are sometimes included thin beds of petrosilex—the strata generally dipping at high angles to the southeast. These petrosilex beds with their accompanying rocks are identical with those which I have described as occurring on the eastern coast of New England, and farther northward along the Bay of Fundy in New Brunswick. They are well seen at Lyon, Saugus, and Marblehead in Massachusetts, and also on the shores of the Passamaquoddy Bay, where they are interstratified, as in the South Mountain, with rocks having the character of the Huronian series; to which great division I have provisionally referred these bedded petrosilex rocks, with the suggestion that they probably occupy a position near the base of the series.[1]

After making the statement that the crystalline rocks of the Green Mountain series belong to a more ancient system, which underlies unconformably the crystalline Cambrian sediments of the Quebec group, Dr. Hunt states that in a letter received by him from Prof. William B. Rogers, dated June 8, 1877, there are statements to the same effect in regard to similar strata in Virginia, as follows:

The sections which I had the pleasure of showing you lately, illustrating the position of the Lower Cambrian beds (our Primal conglomerate, etc.) in their contact with the crystalline and metamorphic rocks of the Blue Ridge in Virginia, form the part of a series embracing the results of some forty transverse explorations made during and since the Virginia geological survey at nearly equal distances across the chain from Harpers Ferry to the North Carolina line. In many of these sections the unconformity of the Cambrian upon and against crystalline and metamorphic rocks is unmistakable and conspicuous, the lower members of the Primal being seen to rest on the slope of the ridge, with northwest undulating dips, on the edges of the steeply southeastward-dipping older rocks. In other cases the Primal beds thrown into southeast dips in the hills which flank the Blue Ridge are made to underlie, with more or less approximation to conformity, the older rocks forming the central mass of the mountain. But even in these instances it is, I think, not difficult to discern the true relations of the strata.[2]

Dr. Hunt follows this quotation with the statement that the crystalline rocks which are the prolongation of the Blue Ridge into southern Pennsylvania have already been described as Huronian by him.

[1] Proc. Amer. Assoc. Adv. Sci., Buffalo, N. Y., 1876, published in 1877, p. 211.

[2] Second Geol. Surv. Penn., Special Report on the Trap Dikes and Azoic Rocks of Southeastern Pennsylvania, Part I, 1878, pp. 198, 199.

When I began the investigation to ascertain by stratigraphic and paleontologic evidence the geologic age of the South Mountain quartzite and the associated schists and shales, I soon discovered that there was little prospect of finding the true geologic succession in the northern portion of the mountain in Cumberland and York counties, owing to the folding of the strata, and also to the fact that there were a number of westward thrusts of lower upon higher beds, and that, as a result of this, the central core of the Blue Ridge has been broken and thrust over on the Lower Cambrian beds, and also, in places, rests apparently conformably upon the latter, all having an eastward dip. The discovery of Olenellus with *Hyolithes communis* in the massive quartzite series in the Mount Holly Ridge, just above Mount Holly Springs, in Cumberland County, proves that the great western mass of quartzite of South Mountain, with the interbedded shales, slates, and conglomerates, are of Lower Cambrian age, but it does not throw any light upon the geologic age of the orthofelsite series of Frazer and the epidote rocks of Rogers. In company with Mr. Arthur Keith, of the United States Geological Survey, who had mapped the Harpers Ferry sheet, an examination was made across the ridges from Mechanicstown, Md., to Monterey, and westward to Pikesville, in Franklin County, Pa. On entering the gorge a little west of Mechanicstown, on the line of the Western Maryland Railroad, an extended series of shales and slates was passed, all having a very high dip to the southeast. About 2 miles from Mechanicstown massive quartzites were met having a high dip to the east, and higher up in the gorge there was a repetition of the slates found east of the quartzites. This section indicates, from the dips of the quartzites, a syncline resting on a considerable thickness of slates and shales. A series of sections, by Mr. Keith, of the western or Blue ridge, extending from a point 11 miles south of Mechanicstown to Harpers Ferry, shows that this same synclinal structure prevails all along the ridge, and that a synclinal fold of massive sandstone forms the summit of the ridge, below which a series of shales rests unconformably upon the subjacent crystalline rocks.[1] The synclinal structure is also shown for the quartzites of the eastern or Catoctin ridge.

From a point 2½ miles west of Mechanicstown to Monterey the road led across the epidote-schists of the central nucleus of the range, which is now a mountain valley between the Catoctin and the Blue ridges. The schists extended to a point one-fourth to one-half a mile beyond the Blue Ridge station, on the Western Maryland Railroad. Fragments of a rhyolitic-like porphyritic rock were also seen, which probably represent the "bedded petrosilex" of Dr. Hunt, as shown 2 miles south of the Monterey road, near Foxville, Md.[2] Along the road

[1] The Structure of the Blue Ridgen ear Harpers Ferry: Bull. Geol. Soc., Amer., Vol. II, 1891, Pls. IV, and V.

[2] Dr. George H. Williams made a detailed study of the volcanic rocks of South Mountain, in Pennsylvania and Maryland. He gives an historic sketch of the various views that prevail as to the character,

beyond Pen Mar toward Pikesville, there was an apparent repetition of the section on the eastern side of the ridge, near Mechanicstown. Subsequently an examination was made of the section from Monterey, Franklin County, Pa., to the valley, on the line of the Waynesboro turnpike. Just west of Monterey a massive quartzite forms a plateau, upon which the Monterey hotel is situated. The dip of the quartzite is slightly to the northwest. A short distance beyond the tollgate the dip to the northwest increases, and a series of sandy and argillaceous shales succeeds the quartzite. Following down the turnpike toward Waynesboro, and near the foot of the ridge, these shales were found to pass beneath a light-colored, hard, compact quartzite dipping northwest, in which numerous remains of *Scolithus linearis* occur. I also found, upon breaking the white quartzite, many fragments of Olenellus, showing parts of the head and thoracic segments. In calcareo-arenaceous layers, just beneath the quartzite, fragments of Olenellus occur associated with specimens of *Camarella minor*. A series of more or less sandy shales next appears, resting upon the Scolithus quartzite and having a northwesterly dip toward the valley. Along the foot of the ridge low hills of shale appear, capped with thin-bedded calcareous quartzite or sandstone. In the latter, *Camarella minor*, *Hyolithes communis*, and fragments of Olenellus were abundant. A little west of the slate hills the limestones of the valley appear. In the limestone a little east of the road, on the East Branch of Little Antie-

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of the rocks of South Mountain, followed by a description of the eruptives, as determined by him. He says:

"The cause of the prevailing misconception regarding the volcanic rocks of South Mountain is not difficult to find. Their accompanying accumulations of tuff beds and breccias, and the fact that they are generally cleaved parallel to the great structure planes of the mountain, have all been readily interpreted as indications of stratification and conformity. The cleavage dip in the sandstone has often been mistaken for bedding, while the thin jointing and slaty structure of the lavas, though a secondary feature, have seemed, to geologists not very familiar with recent volcanic rocks, sufficient proofs of sedimentary origin.

"In spite of great age and some alteration, however, the volcanic rocks of South Mountain have preserved all the essential characteristics of our recent rhyolites and basalts in such perfection that the proofs of their real nature are, to the student of comparative petrography, overwhelming, while to all who will candidly examine them they must be at least convincing."

In relation to the age of the South Mountain volcanics he says: "The age of the South Mountain volcanics and their relations to the sandstone in which Mr. Walcott has recently identified the Lower Cambrian fauna, are points of great interest. The hypothesis of the Pennsylvania geologists that the greenstones and felsites lie above the sandstone is evidently incorrect. It may, however, be regarded as an open question whether the volcanic rocks represent a much older horizon, which was already eroded before the sandstone was deposited, or whether they were, in part at least, contemporaneous with the sandstones.

"The entire absence of sandstone as inclusions in the lavas, as well as in all the accumulations of pyroclastic material; the observations of Keith, Geiger, and Walcott, that the sandstone lies flat or in synclinals; and the sections made by Miss Bascom across Monterey Peak, Pine Mountain, Jack's Mountain, and Haycock, near Monterey, all indicate that the sandstone is altogether above the volcanic rocks, and that it has been only sporadically left by erosion on the east side of the mountain in Pennsylvania. In Maryland the volcanic rocks are flanked both on the east and west by sandstone. No alternations of relatively thin beds of sandstone and lava have thus far been observed. The contacts of the sandstone above the porphyry on the old tapeworm railroad southwest of Maria's Furnace, and above the greenstone in the Jack's Mountain railroad tunnel are both admirable exposures, but both seem to be thrust planes and are not contacts of original deposition.

"The South Mountain volcanic rocks therefore become, not merely in their petrographical character and richness in metallic copper, but also in their stratigraphical position, comparable with the Keewenawan or Nipigon series of Lake Superior."—Am. Jour. Sci., 3d ser., Vol. XLIV, 1892, pp. 482-496.

tam Creek, and about 3 miles east of Waynesboro, Kutorgina n. sp. and fragments of the head and thoracic segments of Olenellus were found.

If reference is now made to the York County section, it will be seen that the upper portion of the Monterey section is essentially a repeti tion of it, from the Scolithus quartzite to the limestones of the valley. The same fossiliferous Scolithus quartzite passes beneath the shales, in which are interbedded calcareous quartzites carrying the Olenellus fauna; these pass beneath the limestones of the valley in York County in which the Olenellus fauna occurs. In the Monterey section, however, there is a series of shales beneath the Scolithus quartzite, that rests upon a massive quartzite forming the summit of the Blue Ridge south of Monterey.

The Blue Ridge was followed south into Maryland and crossed at several points before reaching Harpers Ferry. All of the sections show the synclinal structure of the shales and quartzites as represented by Messrs. Geiger and Keith in their paper on the structure of the Blue Ridge near Harpers Ferry.[1] South of Keedysville, Washington County, Md., the quartzite capping the slate hills west of the main ridge was observed to pass conformably beneath the limestone at Eakles Mills, and *Hyolithes communis* and fragments of Olenellus were found in the calcareous quartzite. The stratigraphic structure south of the Monterey section is complicated at and near Harpers Ferry by the massive quartzite's forming a syncline and by its being thrust to the westward over the more recent shales, slates, and limestones. The structure is still more obscured by the fact that the hills of shale (capped by the Olenellus quartzite) are thrust, on the line of a fault, over on limestones. which, in an unbroken section, rests upon the quartzites.

It was this primary folding, and subsequent westward thrusting on the line of two or more faults, of the older upon the more recent strata, at and to the north and south of Harpers Ferry, that led Messrs. Geiger and Keith to consider that the lower quartzites rested conformably upon the limestones and were of Silurian age.[2]

Returning to the study of South Mountain with the information gained between the Potomac and the line of the Chambersburg and Gettysburg pike, in Pennsylvania, and studying Dr. Frazer's sections (Nos. 7, 8, 9, 10, 11, and 13)[3], and also reading the descriptions of them, as well as Professor Lesley's description of South Mountain (as contained in Vol. I of his final report), one sees that these investigators have misinterpreted the true geologic structure of the mountain and the relations of the rocks composing it. Professor Lesley states that a massive fault must run along the foot of the mountain, along the low drift-filled

[1] Bull. Geol. Soc. Amer., Vol. II, 1891, Pls. IV and V.

[2] Structure of the Blue Ridge near Harpers Ferry, Va.: Bull. Geol. Soc. Amer., Vol. II, 1891, pp. 155–163, Pls. IV and V.

[3] Second Geog. Surv. Penn., Report of Progress on the Counties of York, Adams, Cumberland, and Franklin for 1875–1877.

valley of Yellow Breeches Creek; and in this I think he is correct, as the Olenellus fauna of the Scolithus quartzite zone occurs but a short distance east of the foot of the mountain in a synclinal fold, at Mount Holly Springs. The great error, however, is the view that the "orthofelsite" series is superior to the conglomerate, quartzites, and schists, which they referred to the lower series, placing the "orthofelsite" series above the quartzite series. The Monterey section shows that the epidotic schists are inferior to the quartzites; and a section west of Wolfsville, Md., shows that the petrosilex or "rhyolitic-like" eruptive occupies a similar position. This type of section is repeated many times, both on the Catoctin and Blue Ridge sides, from the Maryland line to the Potomac, and south through Virginia.

Professor Rogers, and also Professor Lesley, referred the offsets of the ranges of hills of South Mountain, as shown in Franklin County, and also on the north end of South Mountain, to the terminations of successive folds of the rocks forming the mountain. My impression is that these offsets, and also the complicated structure of the mountain, arise partly from folding, but more largely from the westward thrusts of masses of strata along the lines of fault of a low hade. This westward thrusting on the fault plane, complicated by previous folding of the strata, leaves masses of the subjacent, pre-Paleozoic rocks resting, in various places, on different members of the Lower Cambrian series, and also appears to interbed the quartzites and schists of the Cambrian in the schists, eruptives, etc., of the Algonkian.[1]

The key to the succession of the lower sedimentary rocks of Maryland and Pennsylvania is contained in the Balcony Falls section of Virginia, although it can be determined by a study of the section at Monterey and to the south along the Blue Ridge, toward Harpers Ferry.

In a letter from Professor Lesley, dated February 22, 1891, he asks:

> Is it possible that there should be agreement between the Balcony Falls section of Virginia and the Mount Holly Spring section, 300 miles apart?

He says, further, after commenting upon the possible relations between the Balcony Falls section and that at South Mountain, in speaking of the strata of the Balcony Falls section:

> But what is 2,000 or 2,500 feet to 10,000 or 20,000 feet of quartzites and slates, making (apparently, not certainly) the South Mountains? We are still in the dark about super and sub positions; about absence or presence of overturn rolls, etc. I am only greatly impressed with the broad fact that we seem to have the Huronian mass rising to view in the South Mountains of the Atlantic States.

I think that the views of Messrs. Frazer and Lesley, that such great thicknesses of strata occur in South Mountain, arise from the fact that

[1] From the finding of the fragments of eruptive rocks in the conglomerates at the base of the quartzite series, and from the numerous synclines showing that the epidotic rocks and also certain rhyolitic eruptives are beneath the quartzite series, I refer the similar rocks of South Mountain to a pre-Paleozoic age; and, as they are not of the characters of the Laurentian crystalline complex, I would refer them to the Algonkian, but not correlate them with the Huronian or with any known division of that group of rocks. Am. Jour. Sci., 3d ser., Vol. XLIV, 1894, p. 480.

these "great thicknesses" are but repetitions of both the Cambrian and pre-Cambrian strata as a result of folding and overthrust faulting, and from failure to differentiate the cleaved schistose eruptives of the Algonkian from the bedded sedimentaries of the Lower Paleozoic.

LANCASTER, BERKS, AND LEHIGH COUNTIES.

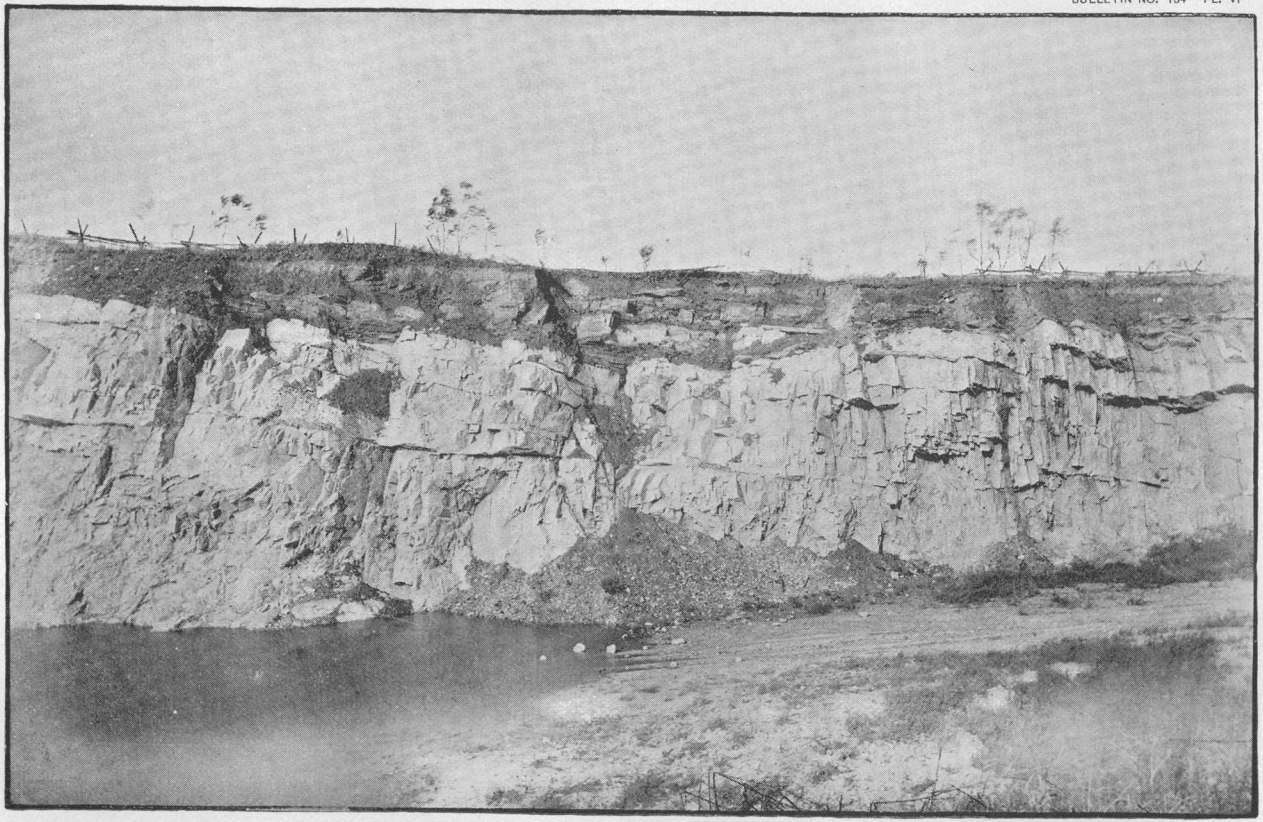
It has been stated that *Hyolithes communis* and fragments of Olenellus were recognized in the material collected from limestones in Lancaster County, on the east side of the Susquehanna River,[1] and that from the closely related stratigraphic arrangement of the rocks of Lancaster County it is probable that all the Lancaster limestones will fall within the Cambrian, unless it be that some portion of the upper series may pass into the Ordovician. This generalization will also apply to the limestone in the adjoining counties of Berks and Chester, and, in fact, to the entire extension of this series northeastward to the Delaware. All of the quartzites that have been referred to the Potsdam will necessarily fall into the Lower Cambrian, as they are beneath the limestones.[2]

Prof. A. Wanner, of York, Pa., accompanied me in the examination of the limestones about the city of Lancaster. His familiarity with the positions of the quarries and natural outcrops enabled us to make a rapid examination of the limestones along Conestoga Creek, and, although no fossils were found, I saw no reason to think that the limestones were not of Cambrian age. We next proceeded to the eastern side of the county, where the southern division of the limestone passes into Chester County. An examination was made of the lower quartzites and the superjacent limestones at Gap, Limeville, and toward Compassville. A few Scolithus borings were noted in the quartzites northeast of Gap, and fragments of Olenellus and specimens of Obolella were found in sandy layers embedded in a shale 1 mile north-northeast of Gap. The section from the top downward, from a point a little east of Gap northwest, is:

5. Massive-bedded, light-colored limestone, with partings and small, interbedded, flattened nodules of mica-schist.
4. Narrow belt of hydromica-schist, with thin layers of hard calcareous sandstone containing Obolella and fragments of Olenellus.
3. Massive beds of bluish-black and nearly white limestone, extensively quarried at Limeville.
2. Narrow belt of shale altered to a hydromica-schist.
1. Quartzite, in the hill northeast of Gap.

We next visited the extensive quarries at Bellemont, on the main line of the Pennsylvania Railroad, 4 miles west of Gap. In the quarries the conglomerate limestone, so characteristic of the Cambrian at Stoners Station, in York County, are beautifully exposed, and numer-

[1] Notes on the Cambrian Rocks of Pennsylvania and Maryland from the Susquehanna to the Potomac: Am. Jour. Sci., 3d ser., Vol. XLIV (Dec., 1892), p. 474.
[2] Loc. cit., p. 475.



CLIFF OF MASSIVE-BEDDED LOWER CAMBRIAN LIMESTONES AT THE QUARRIES ON THE LINE OF THE PENNSYLVANIA RAILROAD AT BELLEMONTE, LANCASTER COUNTY, PENNSYLVANIA.

Bluish-black at base, white above, and capped by thinner layers of a dark, arenaceous limestone.

ous photographs were taken of the conglomerate beds, showing their positions between the evenly bedded limestones. The limestones and conglomerates belong to No. 3 of the Gap section, and are overlain by a belt of shale in which massive beds of a fine limestone conglomerate occur. No time was given to searching for fossils.

Pl. VI illustrates the massive-bedded limestone beneath the conglomerate limestone. This bed is very persistent, and is the source of most of the limestone quarried for the limekilns of this section. Pl. VII is a view taken about one-fourth of a mile to the eastward, where the massive bed of limestone is capped by the conglomerate band, a thin bed of dark, shaly limestone intervening between them. Higher up in the section, about one-fourth of a mile north, the upper massive limestone is exposed in some extensive quarries. This is more siliceous than the beds below, and it breaks up into angular fragments, so as to give the appearance, when viewed at a little distance, of a cliff of quartzite or crystalline rock (Pl. VIII). In the immediate vicinity of the Bellemont quarries one of the characteristic limekilns of a generation ago is in a fair state of preservation. As these are rapidly passing away, a photograph of this kiln was taken, and it is reproduced in Pl. IX.

The discovery of the Olenellus fauna in the limestone in the eastern portion of Lancaster County, north of Gap, taken in connection with the eastern section of York County, compels the reference of the so-called Potsdam rocks of Chester County, with their superjacent limestones, to the Cambrian. As mentioned previously (p. 28), it is quite probable that the limestones toward the Triassic area, in the northern portion of Lancaster County, may be of Ordovician age, but this can be proved only by the discovery of the fauna.

NORTHERN BELT OF LIMESTONE.

As shown by the geologic map of Pennsylvania (1884), the northern belt of limestone enters the State in Franklin County, and then turns to the northeast in Cumberland County, crosses the Susquehanna at Harrisburg, and extends on eastward across Dauphin, Lebanon, Berks, Lehigh, and Northampton counties, to the Delaware River. The Olenellus fauna was found in the quartzites of South Mountain in Adams County, as well as in the lower portions of the limestone in Franklin County.[1] From this, and the fact that the lower portions of these limestones and the superjacent quartzites or sandstones were known to be of Lower Cambrian age in their extension into New Jersey, I began the examination of them in the vicinity of Reading, where their relations to the Reading sandstone are well defined. The *Scolithus linearis* occurs abundantly in the quartzites of Penn Mountain, east of Reading, and on the south side of Neversink Mountain, across the Schuylkill. In the upper layers of the sandstone or quartzite I obtained

[1] Loc. cit., p. 478.

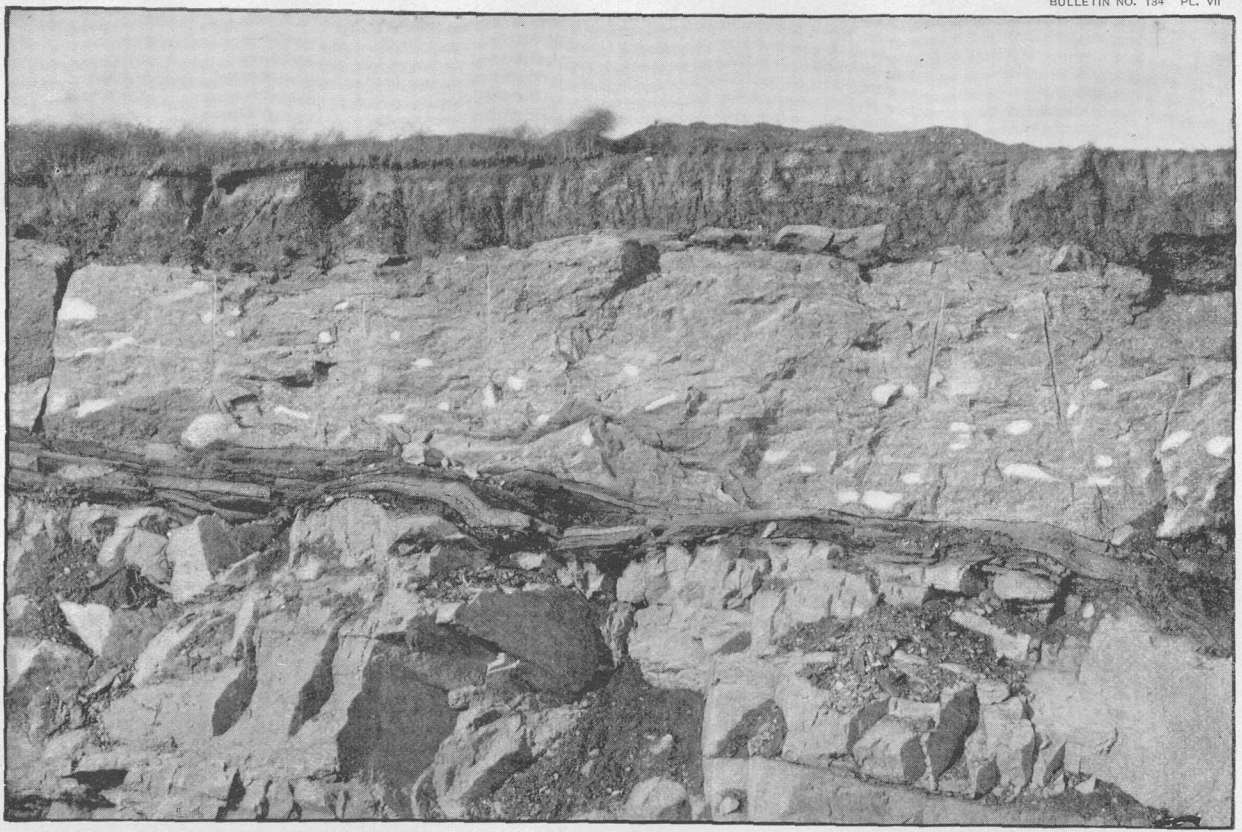
Hyolithellus micans and fragments of a species of Olenellus. This locality is about one-half mile above Klappenthal Station, on the Philadelphia and Reading Railroad, and the terminal station of the electric road running out of Reading over the Neversink Mountain. West of the first railroad cut above the station, between the cut and the stone crusher, thinner beds of quartzite are met with that carry fossils. The quartzites are more or less contorted and folded, but their stratigraphic relations to the main quartzites of the mountain and to the adjoining limestones are readily determined. No fossils were observed in the limestones.

The sections in the vicinity of Allentown and Bethlehem were examined and found to be essentially the same as at Reading, the quartzites passing beneath the limestone. In the quarries at Catasauqua, 4 miles north of Allentown, I noted the occurrence of a large Pleurotomaria, of the type of *Pleurotomaria canadensis*, of the Calciferous horizon in New York and Canada. In the report of the Second Pennsylvania Geological Survey of Lehigh and Northampton counties the localities of fossils are all represented as being on the northern side of the outcrop of limestone, in the strata that dip to the northward beneath the superjacent shales. The Trenton horizon is represented as in the limestone immediately beneath the shales (called "Hudson"); and lower down, in massive limestone, species of Maclurea or Eomphalus, which indicate the Chazy horizon, have been found. This distribution of faunas is the same as in Franklin County, where the Lower Cambrian fauna occurs at the base of the limestone, near the quartzites, and the Trenton fauna at the summit, near the base of the superjacent shales.

The limestones were examined in the vicinity of Easton, along Bushkill Creek and the shores of the Delaware River. No fossils were found, with the exception of a species of Cryptozoan; but from the similarity of the limestone to that of the lower portion of the series near Allentown, Reading, and in Lancaster County, it is quite probable that they represent the Lower Cambrian portion of the section. North of Easton 5 or 6 miles, in the vicinity of Churchville, fossils that indicate the Trenton horizon were discovered by the Pennsylvania Survey. I think it is only a matter of detailed search and patience to discover localities of fossils, both in quartzites and limestones, throughout this belt, from where it enters the State from Maryland to where it crosses the Delaware into New Jersey.

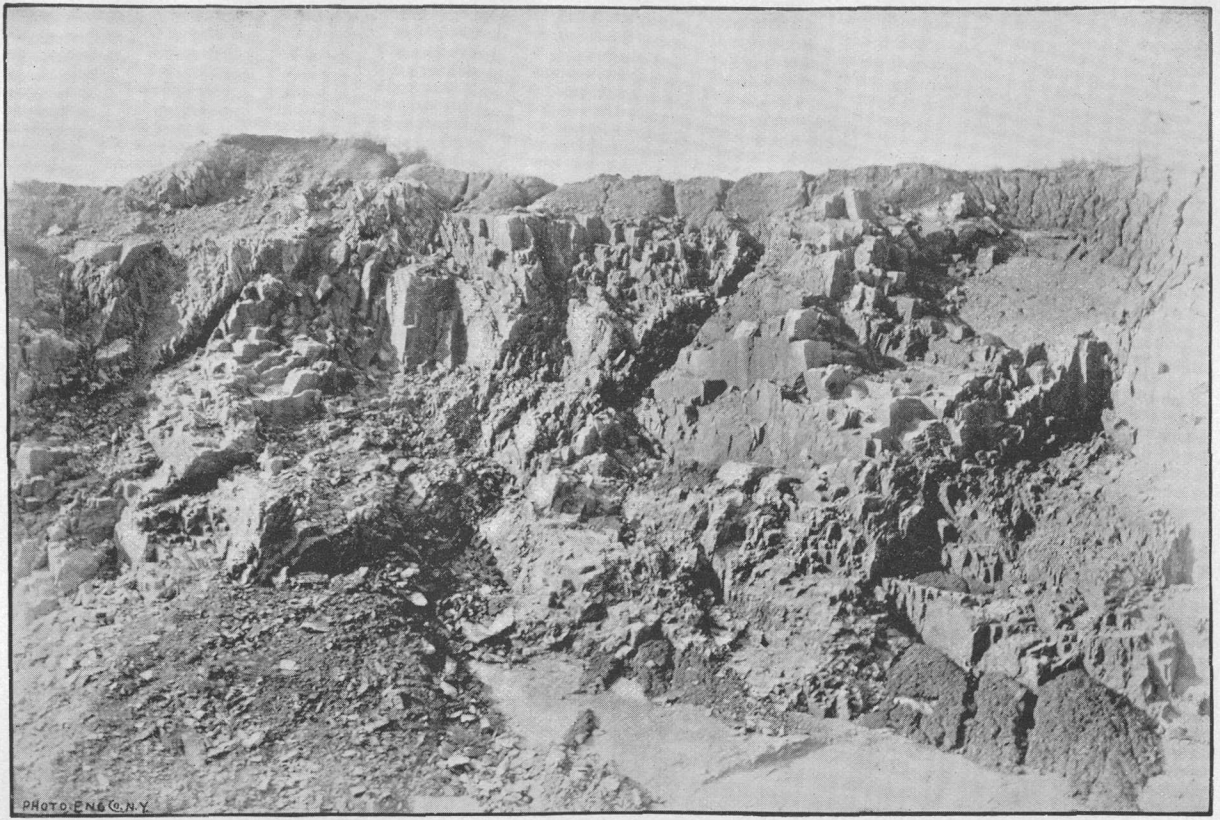
If we follow the line of the strike of the limestones across the Delaware into New Jersey, the same type of section is found to extend northeasterly across that State and into Orange County, N. Y. At Hardistonville, Sussex County, N. J., Dr. Beecher discovered the Olenellus fauna in the blue limestones resting on the basal quartzite.[1] The fossils are found on the southeastern side of the limestone belt, and on the northwestern side the limestones dip beneath the shales, as

[1] Geol. Surv. New Jersey, Ann. Rept. State Geologist, 1890, pp. 31, 43, 49.



LOWER CAMBRIAN LIMESTONE EXPOSED IN QUARRIES AT BELLEMONTE, LANCASTER COUNTY, PENNSYLVANIA, ON THE LINE OF THE PENNSYLVANIA RAILROAD, A SHORT DISTANCE EAST OF PL. VI.

The massive limestones are here capped by a band of limestone conglomerate that rests on the thin-bedded limestone shown in top of quarry, Pl. VI.



MASSIVE-BEDDED, LIGHT-GRAY, SILICEOUS LIMESTONE, IN QUARRIES ONE-FOURTH MILE NORTH OF PENNSYLVANIA RAILROAD TRACKS, BELLEMONTE, LANCASTER COUNTY, PENNSYLVANIA.

The limestone breaks into angular fragments on the lines of the bedding and cleavage planes.

in the Pennsylvania section. In the geological report of New Jersey for 1868, pages 131 and 132, numerous localities of the fossiliferous Trenton limestone are described, and a section is given showing the limestone passing beneath the shales to the westward.

In the summer of 1894 I found at a point 4 miles northeast of Newfoundland, N. J., fragments of Olenellus in the limestone resting on a bedded quartzite which was in contact with the pre-Cambrian gneiss. The Cambrian rocks at this point are represented by a lower quartzite 10 or 15 feet in thickness, a massive-bedded, siliceous limestone that may be 200 feet thick, and a series of shales of inconsiderable thickness that pass beneath the Silurian (?) conglomerate of Kanouse Mountain.[1]

CORRELATION.

Reference has already been made to the similarity, noted by Professor Lesley, between the rocks of South Mountain and those described by Professor Fontaine in the Balcony Falls section of Virginia. The latter section, as described by Mr. H. D. Campbell, in 1885, is as follows, from the base up:

Section at Balcony Falls, Va.

	Feet.
8. Scolithus sandstone	350
7. Slates	120
6. Sandstone	90
5. Slates	700
4. Hard sandstone	150
3. Slates	500
2. Sandstone	360
1. Conglomerate	120
Total	2,390

He further states that, away from the river some distance, there are about 600 feet more of sandstone and friable slate before the limit of the Potsdam formation is reached.[2]

The sandstones and slates of the section, with the exception of No. 8 (the Scolithus sandstone), and the superjacent shales, are all more or less feldspathic. The Scolithus sandstone and the beds just above it are known to be of Lower Cambrian age,[3] and Cambrian fossils were found near the summit of the superjacent shales beneath the limestones.

Prof. William B. Rogers traced, as he thought, the Primal sandstones and slates of the Balcony Falls section across Virginia to Harpers Ferry, where they crossed the Potomac and extended on northward along the Blue Ridge to South Mountain, southwest of the

[1] Am. Jour. Sci., 3d ser., Vol. XLVII, 1894, pp. 309–311.

[2] The Potsdam Group east of the Blue Ridge, at Balcony Falls, Va.: Am. Jour. Sci., 3d ser., Vol. XXIX, 1885, p. 472.

[3] Notes on the Cambrian Rocks of Virginia and the Southern Appalachians: Am. Jour. Sci., 3d ser. Vol. XLIV, 1892, p. 53.

Susquehanna, in Pennsylvania. His various sections of the Blue Ridge show an overturn of the Primal strata to the westward, which gave that and the superjacent Valley limestone an easterly dip. If he had at that time understood the phenomena of thrust faults, I think he would have interpreted the structure to be a thrusting (often of a synclinal fold) of the older Primal beds over on the superjacent limestone, instead of an overturned anticlinal fold.

The section at Monterey, and along that portion of the Blue Ridge, as estimated from the data obtained by Mr. Keith to the south and from the Monterey section, is as follows, reading from above downward:

Section at Monterey, Va.

(The upper portion of the section is preceded by the Valley limestone, more or less of the lower portion of which is probably of Middle and Upper Cambrian age.)

	Feet.
6. Mottled limestone, with intercalated sandy and shaly layers. Fossils: Kutorgina n. sp. and fragments of Olenellus	800 to 1,000
5. Sandy shales, with a series of calcareous quartzite near the summit. Fossils: *Camarella minor, Hyolithes communis,* and fragments of Olenellus. About	450
4. Scolithus quartzite, with interbedded calcareous sandstones and shales. Fossils: *Camarella minor* and fragments of Olenellus	500
3. Sandy shale, with interbedded layers of quartzite	800
2. Coarse-grained and bluish-gray quartzite	1,000 to 1,200
1. Shales and slates, well shown near Mechanicstown, Md., and in numerous sections along the Blue Ridge	300 to 400

(At several localities the shales of No. 1 appear to be replaced by bands of conglomerate, and many of the layers of No. 2 are to a greater or less extent a conglomerate.)

The section includes from 3,000 to 3,500 feet of sandstones and shales before reaching the limestones. In a number of localities a conglomerate was observed in the lower sandstone series in which fragments of the pre-Paleozoic crystalline rocks were embedded. This phenomenon was observed on South Mountain, in the conglomerate mentioned by Professor Lesley, and also along the Blue Ridge and the Catoctin Ridge to Harpers Ferry, the conglomeritic character of the rocks varying very much in the character and size of the coarser material. The feldspathic character of these shales and sandstones is very distinctly marked beneath the Scolithus quartzite, in both the Balcony Falls and the Monterey sections. If these two sections are compared with that at Chickies Rock and south to Columbia, in Lancaster County, Pa., it will be at once observed that the Scolithus quartzite, while the highest band of quartzite in the Balcony Falls and the Monterey sections, is the lowest in the Chickies Rock section, which has the lowest feldspathic sandstone and shales apparently above the Scolithus quartzite. It is from this fact that it is stated, in the first part of this paper, that the feldspathic sandstones and shales were thrust over on the Scolithus sandrock in the Chickies section.

VIEW OF AN OLD LIMEKILN AT BELLEMONTE, LANCASTER COUNTY, PENNSYLVANIA, ON THE MAIN LINE OF THE PENNSYLVANIA RAILROAD.

On Pl. II of Bulletin No. 81 of the United States Geological Survey, section 9 is intended to illustrate the Cambrian rocks of central Pennsylvania. It gives the data known at that time, but my recent reconnaissance has disclosed the fact that a section similar to that of Tennessee (section 11) will more fairly represent the Cambrian rocks on the Susquehanna and to the southwest into Maryland.

The discovery of the Olenellus or Lower Cambrian fauna in the Reading sandstone practically completes the correlation of the South Mountain, Chickies, and Reading quartzites, and establishes the correctness of the early correlations of McClure, Eaton, Emmons, and Rogers. They all considered the basal quartzite as the same formation from Vermont to Tennessee; and the discoveries of recent years have proved that the basal sandstones of Alabama, Tennessee, and Virginia (Chilhowee quartzite); Maryland, Pennsylvania, and New Jersey (the Reading quartzite); New York and Vermont (Bennington quartzite), were all deposited in Lower Cambrian time, and that they contain the characteristic Olenellus fauna throughout their geographic distribution. The superjacent limestones carry the Olenellus fauna in their lower portions in northern and southern Vermont, eastern New York, New Jersey, and Pennsylvania. To the south of Pennsylvania the lower portions of the limestones appear to be represented by shales, and the Upper and Middle Cambrian faunas are found in the lower half of the Knox dolomite series of Tennessee, and they will probably be discovered in the same series in Virginia and Maryland when a thorough search is made for them. The same may be predicted, but with less assurance, for the northern belt of limestone crossing Pennsylvania into New Jersey, as the limestones between the Olenellus zone and the Trenton zone represent the intervals of the Middle and Upper Cambrian and the lower Ordovician, or the Calciferous and Chazy zones of the New York section. The working out of the details of this section in southeastern Pennsylvania is an interesting problem, left for solution to some geologist who has the necessary paleontologic training, and who will not be discouraged by the prospect of a good deal of hard work before the desired result can be obtained.

The problem of where to draw the line in this series of limestones, on a geologic map, between the Cambrian and Ordovician, is one that will seriously embarrass the geologist, but I anticipate that either lithologic or paleontologic characters will be discovered by which the two groups can be differentiated. If not, the limestones must be colored as one lithologic unit or formation, as on Pl. I, and the approximate line of demarcation between the Cambrian and Ordovician must be indicated in the columnar section accompanying the legend of the map.

INTRAFORMATIONAL CONGLOMERATES.

In a recent article[1] I have discussed under this title a conglomerate formation, some of the principal illustrations of which occur in the Cambrian rocks of Pennsylvania. As this is a somewhat unusual phenomenon, but one that will be seen with comparative frequency in Pennsylvania, I here append my observations on the subject, and also reproduce the illustrations of the Pennsylvania localities.

DEFINITION OF TERM AND ILLUSTRATION.

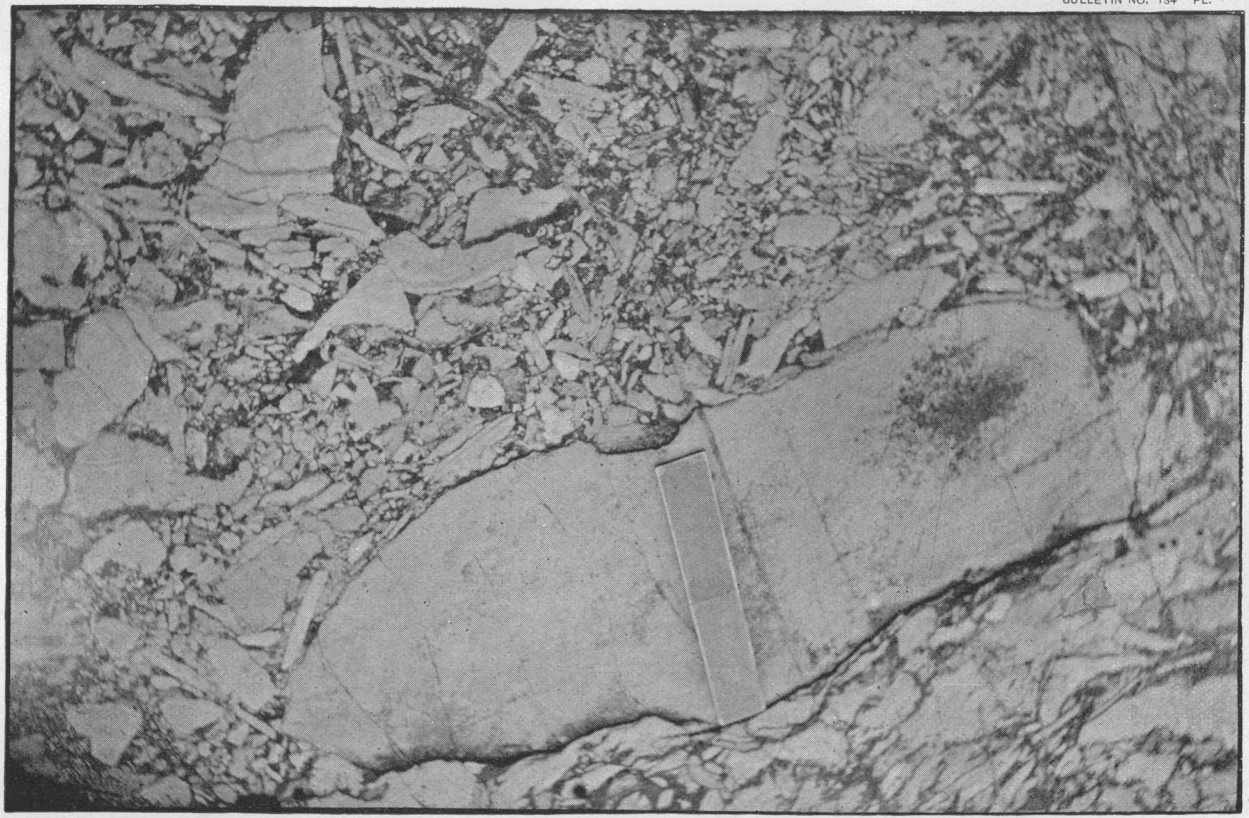
An intraformational conglomerate is one formed within a geologic formation of material derived from and deposited within that formation. An illustration occurs in the old limestone quarries on the east shore of the Hudson, below Schodack Landing, Rensselaer County, N. Y. The section is formed of thinly bedded limestone carrying the typical Olenellus fauna. Toward the summit of the quarry a band of limestone conglomerate rests conformably on the bedded limestone. Pebbles and fragments of several varieties of limestone occur, in which fragments of typical species of the Olenellus fauna were found. The conglomerate band varies in thickness from 2 to 6 feet, and is capped by thinly bedded limestones that carry the same species of fossils as the limestones beneath the conglomerate and the bowlders in the conglomerate. It shows that the limestone pebbles, bowlders, and brecciated fragments were formed from a calcareous sediment sufficiently consolidated to be broken up and more or less rounded by attrition, and these collected to form a bed of conglomerate, the matrix of which is usually calcareous. This section clearly proves the formation of conglomerate within the Lower Cambrian terrane, the materials of which were derived from limestones deposited during Lower Cambrian time.

The conglomerate at the locality described is not so clearly marked as are some in the Lower Cambrian terrane of Lancaster and York counties, Pa., and the conglomerates at the base of the great Ocoee series of Tennessee. The limestone conglomerates of the Cambrian and Ordovician of the St. Lawrence Valley are not typical illustrations of true intraformational conglomerates, but I shall speak of them, as they appear to have been formed under somewhat similar conditions.

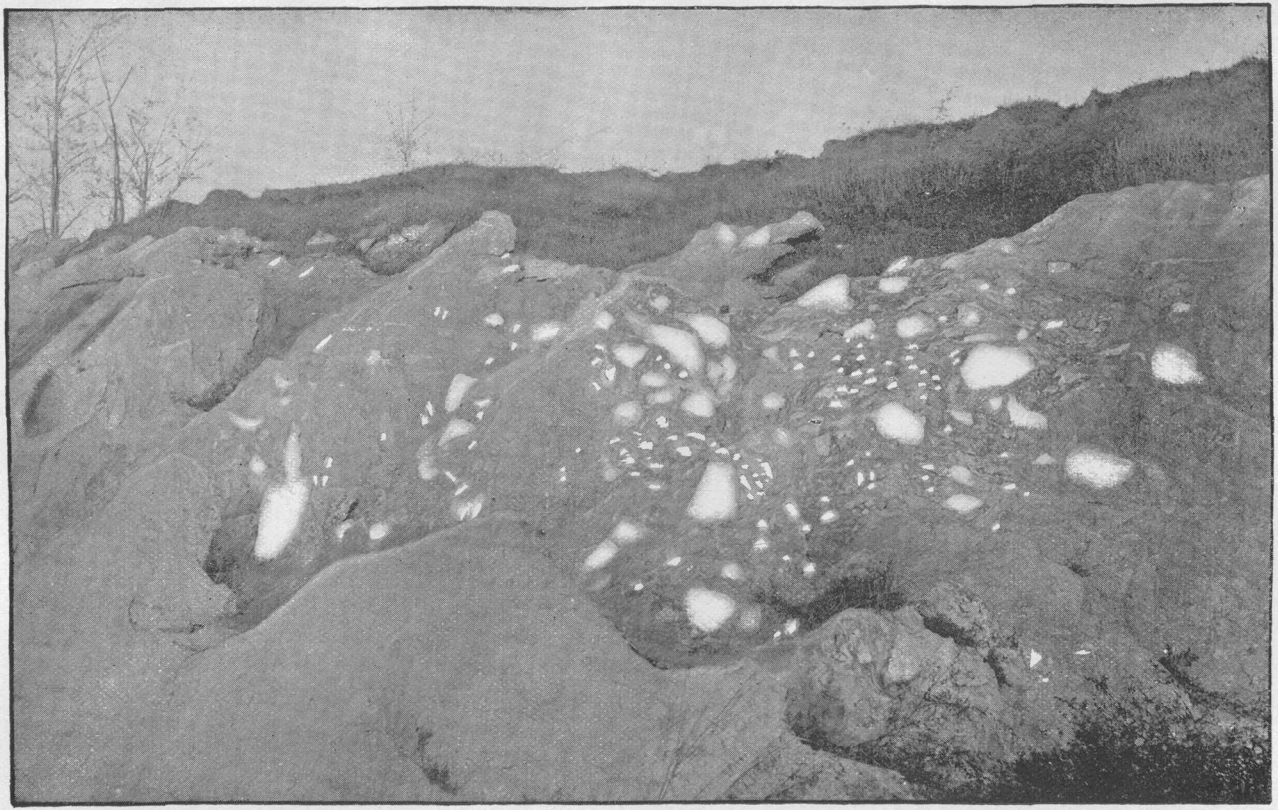
CANADIAN LOCALITIES.

Sir W. E. Logan has graphically described the limestone and conglomerates of the south shore of the St. Lawrence at Trois Pistoles, Bic, Métis, the vicinity of Quebec, and the west coast of Newfoundland.[2] During the summer of 1889 I had an opportunity to examine the sections of the Ordovician and Cambrian rocks in the vicinity of

[1] Bull. Geol. Soc. Amer., Vol. V., 1894, pp. 191-198, Pls. V-VII.
[2] Geology of Canada, 1863, pp. 227, 260, 261.



BRECCIATED LIMESTONE CONGLOMERATE IN LOWER ORDOVICIAN SOUTHEAST OF HIGHGATE SPRINGS, FRANKLIN COUNTY, VERMONT.



EXPOSURE OF LIMESTONE CONGLOMERATE IN LOWER CAMBRIAN LIMESTONE IN QUARRY ON EAST SIDE OF YORK, PENNSYLVANIA, WITHIN THE CITY LIMITS.

Quebec, and I was very much impressed by the mode of occurrence of the limestone conglomerates. The lowest bed of conglomerate occurs in the Sillery shales on the south shore of the St. Lawrence below Levis and on the south shore of the island of Orleans. The limestone bowlders show transportation, and are mingled with pebbles of quartz, sandstone, etc. The Olenellus fauna occurs abundantly in the fragments of limestone, but the source of the limestone is unknown. It is, however, of Cambrian age, and it has been redeposited about 1,500 feet from the summit of the series of shales, sandstones, etc., that are referred to the Cambrian.[1]

The lower bed of limestone conglomerate at Point Levis occurs near the base of the Ordovician, in the Point Levis shale. It is made up of large and small bowlders of limestone, carrying the Upper Cambrian fauna, that are embedded in the limestone matrix in which occurs the typical Calciferous fauna. The matrix is a hard, gray, impure limestone, which forms solid layers that were traced for over 500 feet on the strike. As in the case of the limestone bowlders carrying the Olenellus fauna, the origin of the bowlders carrying the Upper Cambrian fauna is unknown, as no beds of limestone of a similar character have been found in the Sillery shales, upon which the Ordovician shales and interbedded conglomerate rest. The matrix of the conglomerate proves the formation to be of lower Ordovician age. In a bed of limestone 50 feet higher up in the section I found additional species of the Calciferous fauna, and in a bed of limestone conglomerate above this the fossils in the bowlders, and in the matrix as well, are of Calciferous age. In a search of two days I failed to find a Cambrian fossil at this horizon, although such a discovery might be anticipated from the occurrence of the older limestones in the conglomerates beneath. This second band of conglomerate in the Levis series appears to be true intraformational conglomerate. The limestone conglomerates embedded in the shales and shaly limestones beneath the city of Quebec are of much less stratigraphic importance than are those at Point Levis; but the same conditions of deposition appear to have existed during the formation of these rocks of middle Ordovician (Chazy-Trenton) time.

VERMONT AND NEW YORK LOCALITIES.

In the passage beds between the Cambrian and Ordovician east of Highgate Springs, Franklin County, Vt., layers of limestone conglomerate occur (Pl. X), some of the fragments of which carry the lower Ordovician fauna. The horizon of the conglomerate appears to be within the range of this fauna, and points to an intraformational origin.

The type that has already been described as occurring at Schodack Landing, N. Y., has been observed at many localities to the north, in Washington County, N. Y., where it is a common feature of the Lower Cambrian terrane.

[1] Am. Jour. Sci., 3d ser., Vol. XXXIX, 1890, pp. 112–113.

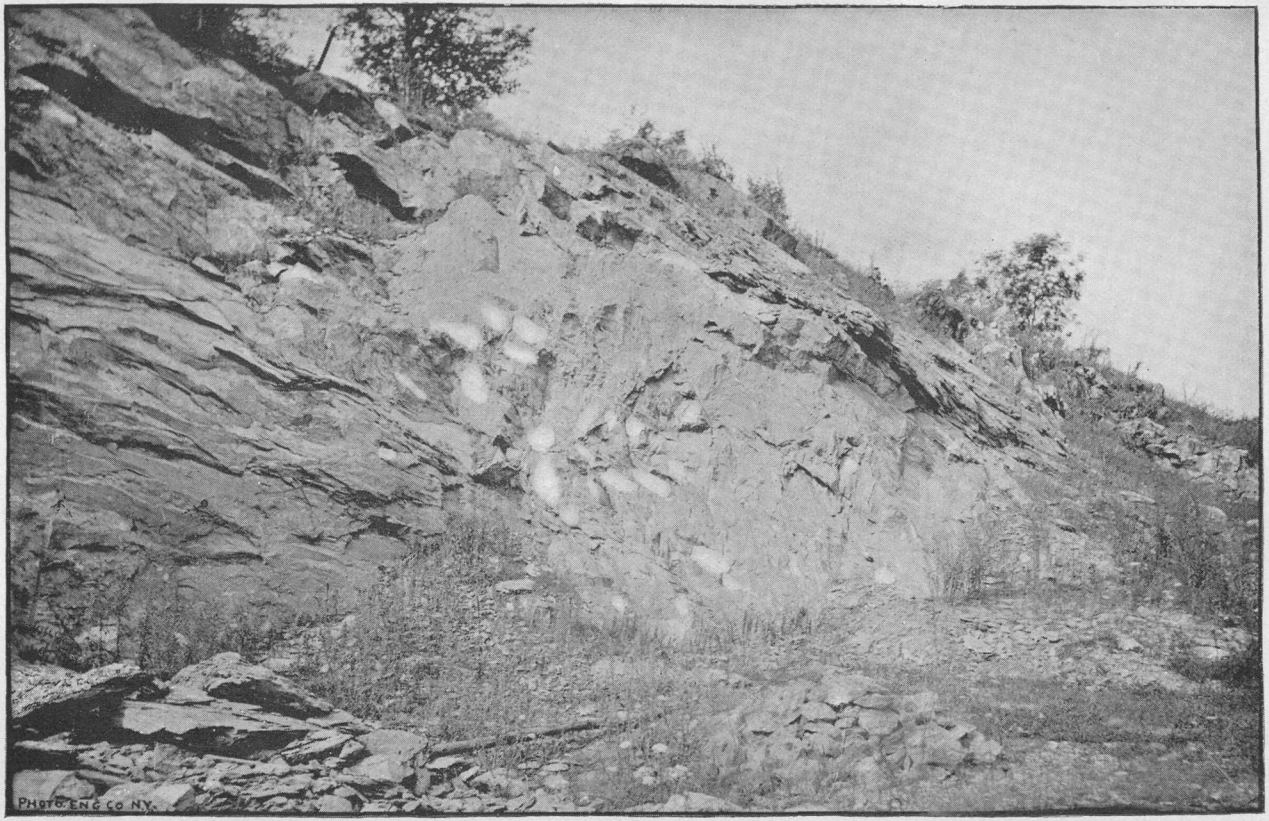
PENNSYLVANIA LOCALITIES.[1]

The succession of Cambrian rocks in York and Lancaster counties, Pa., is very clearly defined. A massive quartzite is succeeded by shales, and then comes a massive-bedded, more or less siliceous limestone that varies in color and composition in its several beds. This massive bed of limestone is succeeded in numerous instances by beds of limestone conglomerate, which are interbedded in more or less thinly bedded, somewhat shaly limestones. One of the most clearly defined sections is exposed at Bellemont, Lancaster County, on the line of the Pennsylvania Railroad. The massive blue and white Cambrian limestones are succeeded by a few feet of a blue, earthy limestone and shale, and upon this there is a bed of limestone conglomerate, from 8 to 10 feet in thickness, that is made up largely of pebbles and bowlders of limestone derived from the limestone beds beneath. (Pl. VII.) A second bed of conglomerate is seen on the roadside to the north.

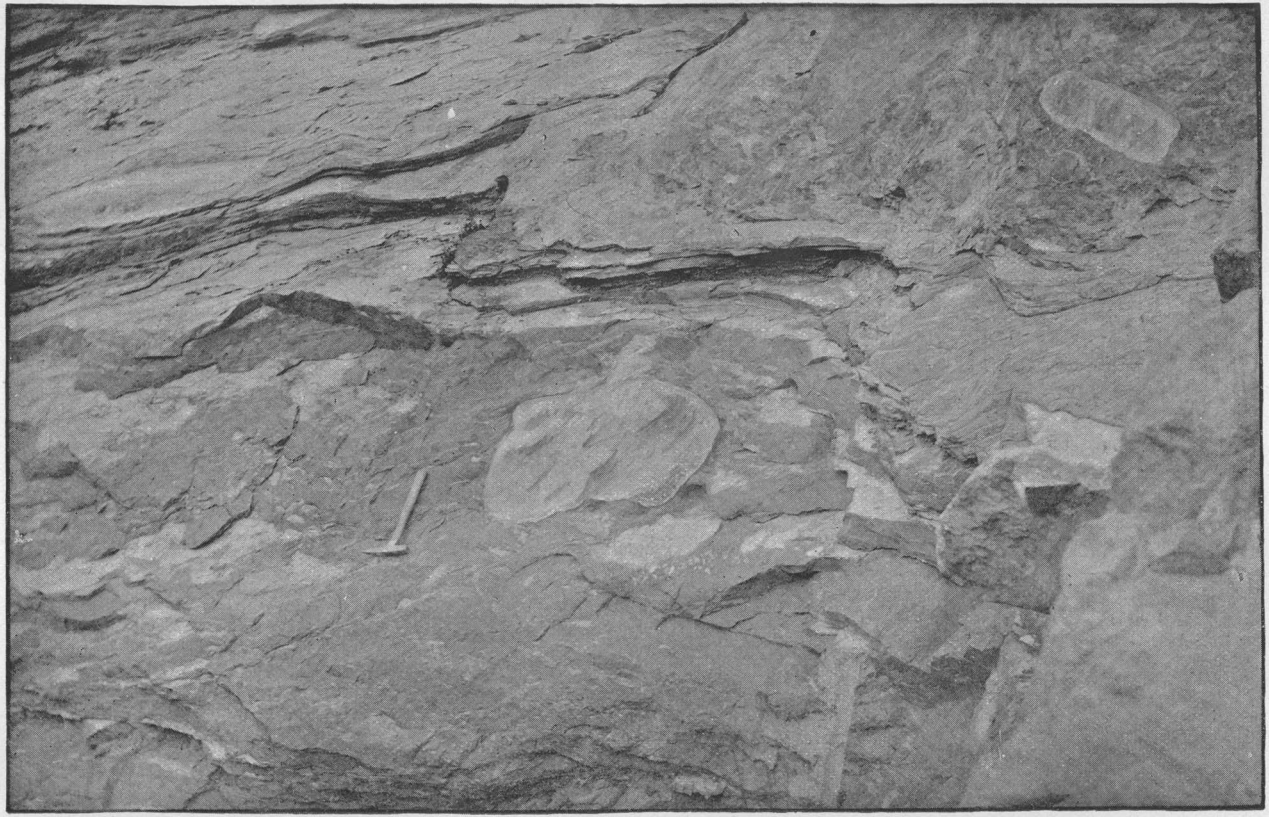
About 40 miles west of Bellemont, at Stoners Station, on the York and Wrightsville Railroad, York County, Pa., an extensive and beautiful exposure of the Lower Cambrian limestones and conglomerate may be seen in an old quarry just east of the wagon road, one-fourth of a mile north of the railroad track. (Pl. XII.) Alternating bands of thinly bedded limestone and massive beds of limestone conglomerate form about 100 feet of the exposed section, in which five beds of the conglomerate limestone are well shown. The basal bed has a fine-grained, gray limestone matrix with brecciated limestone fragments in it, which range in size from that of small shot to masses 3 feet in diameter. These pebbles and bowlders vary in lithologic character, some resembling the matrix and others being oolitic, arenaceous, semi-marbleized, and shaly limestones. The thinly bedded limestones separating the conglomerate bands are from 4 to 6 feet in thickness, and are very clearly defined.

In the second band of conglomerate the larger bowlders occur in the lower portion. The other three beds vary in details, but they are all formed of the same type of rock. One of the upper beds contains a multitude of small fragments of limestone. It was impracticable to obtain a photograph of the basal beds, which contain the largest bowlders. Pl. XII illustrates the evenly bedded limestones above and beneath the third band, and also shows the character of some of the limestone bowlders. In the shaly limestone at the base of this bed a larger bowlder, 2 feet or more in diameter, is entirely embedded in the shaly limestone. This bowlder, as shown in Pls. XIII and XIV, was evidently deposited on the bed of the sea, and the calcareous mud

[1] Mr. Frederick Prime, jr., noted the brecciated conglomerates in the limestone of Lehigh and Northampton counties, Pa. They occur between bands of unbroken limestone, and he explained the phenomenon by the fracture of unyielding beds between two more pliable ones and recementing in situ by the percolation of calcareous waters. (On the Paleozoic Rocks of Lehigh and Northampton counties, Pa.; Amer. Philos. Soc., Proc., Vol. XVII, 1878, p. 250.)



LIMESTONE CONGLOMERATE AT QUARRY ONE-FOURTH MILE NORTH OF STONERS STATION, YORK AND WRIGHTSVILLE RAILROAD, YORK COUNTY, PENNSYLVANIA.



VIEW OF A BOWLDER IN THE THIN-BEDDED LIMESTONE BETWEEN THE BEDS OF LIMESTONE CONGLOMERATE AT QUARRY ONE-FOURTH MILE NORTH OF STONERS STATION, YORK AND WRIGHTSVILLE RAILROAD, YORK COUNTY, PENNSYLVANIA.

gathered quietly about it. At about the same horizon, in a quarry on the east side of York, a massive bed of limestone conglomerate is beautifully shown. A photograph of it is reproduced as Pl. XI.

The quartzites, shales, and limestones beneath these beds of conglomerate are known to carry the Lower Cambrian or Olenellus fauna; and the same fauna, with the exception of details of variation of species, occurs in the limestones and shales above the conglomerates, thus placing the latter within the definition of intraformational conglomerates.

VIRGINIA LOCALITIES.

Mr. M. R. Campbell[1] informs me that in the vicinity of Radford, Va., there is a formation that appears to be a true intraformational conglomerate. He states that it is in the great Cambro-Silurian limestone, and consists of a yellowish-white, chalky limestone matrix in which are embedded rounded fragments of limestone that are similar in composition to the matrix, and that can be distinguished from it only with difficulty. A few small grains of foreign material were observed. The exact stratigraphic horizon could not be determined, owing to the complexity of the structure and the poor exposures. Two miles below Radford the actual contact was observed between the conglomerate and the bedded limestone, where the former rests on the cut edges of the folded limestones beneath. Mr. Campbell believes this indicates shore conditions, contortion of the limestone deposits, and their elevation above sea-level to form cliffs that supplied material for later beds of the same great formation.

Another case of this kind was observed by Mr. Campbell at a horizon northwest of Bristol, Va. He found that here the conglomerate occurs in a bed of shaly limestone, only a few feet thick, that belongs in the Nolichucky (Cambrian) shales. This bed appears to have been broken up largely into flat fragments that were quite well worn on their edges, and then redeposited in the same bed and cemented into a solid mass of limestone. The peculiar features of this deposit are its extreme thinness and apparent freedom from all marks of erosion. It is quite persistent, and no evidence of an unconformity was observed.

TENNESSEE LOCALITIES.

The intraformational conglomerates already described have been identified as such by the presence of similar fossils in the bowlders of the conglomerate and the superjacent and subjacent bedded limestones. Those about to be described are identified entirely by lithologic characters. These, however, are so clearly defined and are of such variety that the conclusions based upon them are considered to be nearly as reliable as those where fossils are present.

In Tennessee these conglomerates occur in the lower portion of the Ocoee terrane of Safford. Mr. Arthur Keith named the basal slate the

[1] Paleozoic Overlaps in Montgomery and Pulaski Counties, Va.: Bull. Geol. Soc. of Am., Vol. V, pp. 175-176.

Wilhite. This slate rarely exceeds 700 feet in thickness, and it is capped by the siliceous Citico conglomerate (Keith). Within the Wilhite slate, especially in the upper 200 feet, and along its strike for over 100 miles, numerous beds of limestone occur. Usually a limestone conglomerate is found in the same section, generally above the bedded limestone. These limestone conglomerates have been cited as proof that the Wilhite slates were of later age than the Ordovician limestones, which, it was assumed, furnished the pebbles and bowlders of the limestone conglomerates; and hence, it was concluded, the Ocoee terrane, instead of being an older formation than the great limestone series of Tennessee, is of later date, and consequently of post-Ordovician age.

In company with Mr. Keith I visited numerous localities of the Wilhite slate in Cocke, Sevier, and Blount counties. At a locality 3 miles S., 65° E. of East Fork, Sevier County, a limestone conglomerate occurs by the roadside, and also on the north side of the road, on Stephen Huff's farm. The bedded limestones vary in texture and color and in the presence or absence of more or less arenaceous material, but the weathered surfaces of many of the beds are very characteristic. At the locality by the roadside there is little, if any, of the bedded limestone exposed, the conglomerates resting on calcareous shale or slate containing compressed lentils of impure bituminous limestone. The conglomerate is formed of brecciated and rounded pebbles and bowlders of limestone and, more rarely, of a fine-grained sandstone. The limestone bowlders vary in lithologic characters from pure white limestone to sandy and siliceous and their various combinations. In color they are blue, gray, black, purple, white, pinkish, dove, etc. About 2 miles to the north of this locality, on Wilhite Creek, there occurs a somewhat similar conglomerate, in which the limestone bowlders reach a diameter of from 3 to 4 feet. A peculiarity of the conglomerate at these places is the presence of large bowlders in the slate above the main body of the conglomerate.

At a locality 2 miles east of Jones Cove, Sevier County, an interesting phase of the conglomerate is the presence of bowlders of a dark, sandy limestone embedded in the mass of the bedded limestone that occurs below and also above the conglomerate. The matrix of the conglomerate is frequently largely made up of a sandy limestone of the same lithologic aspect as the bedded limestones out of which the bowlders of the conglomerate were made. The limestone conglomerate was also noted at a locality 3 miles south of Del Rio, Cocke County, where it occurs above the limestone in the Wilhite slate.

One of the best localities at which to study the relations of the limestones and conglomerates is on the north side of the entrance to the narrows of the Little Tennessee River, in Blount County. Here the bedded limestones in the Wilhite slates are beautifully exhibited, and above them the limestone conglomerate is strongly marked, and bowlders of the limestone over 6 feet in diameter occur in the lower portion of the Citico conglomerate. Another peculiarity at this locality is that

NEARER VIEW OF THE BOWLDER SHOWN IN PLATE XIII, SEEN FROM A DIFFERENT DIRECTION.

the limestones within the Wilhite slate were broken up and many of the fragments rounded to form a bed of conglomerate just above the horizon of the limestone beds from which, elsewhere, they were derived, and the same process was repeated with the bed of conglomerate. We found in an upper bed of conglomerate bowlders formed of masses of conglomerate of the same character as that in the stratum some distance below in the section. In this upper conglomerate numerous quartz pebbles of the same character as those of the Citico conglomerate are embedded in the limestone matrix. Special effort was made, by both Mr. Keith and myself, to discover evidence of the presence of limestones of a character different from that of those found conformably bedded in the Wilhite slate, but without success. The limestones of the Wilhite slates are so marked in their lithologic characters, and the bowlders in the conglomerates have lithologic characters so similar, that we did not hesitate to refer the source of the material of the latter conglomerate to the limestone beds within the Wilhite formation. At one locality, 2 miles S., 10° W. of Sweetwater, Cocke County, a sandstone rests unconformably upon the Knox limestone and contains rounded pebbles of the limestone carrying the characteristic fossils which are embedded in the limestone beneath the sandstone. This sandstone occurs in the isolated outcrop and is not known to be of Ocoee age.

ORIGIN.

The relation of the bedded limestone to the superjacent conglomerates proves that the calcareous mud which was subsequently consolidated into the limestones solidified soon after deposition. This is shown by the presence in the conglomerate of rounded pebbles and angular fragments of limestone with sharp, clear-cut edges. The presence of the conglomerates above the limestone beds, from some portion of which they were derived, leads me to believe that the sea bed was raised in ridges or domes above the sea-level and thus subjected to the action of the seashore ice, if present, and the aerial agents of erosion. From the fact that the limestones upon which the conglomerates rest rarely, if ever, show traces of erosion where the conglomerates come into contact with them, the inference is drawn that the débris worn from the ridges was deposited in the intervening depressions beneath the sea. In the case of the conglomerates of the Wilhite slates of Tennessee, it is exceptional to find a bedded limestone above them; but within the Lower Cambrian of Pennsylvania and New York the conglomerates are interbedded in the limestones.

Large bowlders of limestone were observed in the Wilhite slates on Wilhite Creek, Tennessee, above the main conglomerate bed, and large bowlders of limestone were observed in the bedded limestones at Stoner's quarry, Pennsylvania. The mode of occurrence of these bowlders, especially those in the limestones at Stoner's quarry, leads to the view that they may have been dropped upon the sea bed from floating ice. No other explanation occurs to me that will account for the transpor-

tation of a bowlder from the shore-line and the placing of it upon the sea bed so as not to disturb to any marked degree the sediment then accumulating. In the special example at Stoner's quarry 2 feet of calcareous mud was deposited in thin layers about the bowlder, and as much more above it, before the introduction of conditions that led to the deposition of the next stratum of conglomerate.[1]

The history of Appalachian sedimentation and mountain-building proves that a more or less constant movement was taking place from Algonkian time to the close of the Paleozoic.[2] This movement was at times greatly prolonged, and resulted in marked topographic features. More frequently the minor movements produced local effects, and some of them resulted in the formation of the conglomerates described.

MODE OF FORMATION OF THIN-BEDDED BRECCIAS.

The mode of formation of a brecciated limestone conglomerate, illustrated by Pl. X, has often puzzled me when studying Paleozoic rocks. Geologists frequently observe layers composed almost entirely of thin-bedded, brecciated limestones, or of sandy or argillaceous shales. In many cases the layers of breccia are not more than an inch or two in thickness and occur between layers formed of undisturbed sediment. The breccia is often composed of angular fragments varying from a quarter of an inch to half an inch in thickness, while in the thicker layers of the breccia fragments an inch or more in thickness occur.

During the summer of 1895, when making observations on the flats exposed at low tide in the inlet west of Noyes Point, Rhode Island, I noticed that when the tide went out before daylight the layer of fine sand and mud exposed to the dry wind and sun during the day hardened, and that when the surface of the water of the incoming tide was broken by small waves the hardened layer was lifted, broken into angular fragments, and piled in some places to a depth of several inches, while in other places it was simply turned over and was very little disturbed. When much disturbed the edges of the fragments were rounded, so as to give them the appearance of having been rolled a considerable distance. In one instance the ensuing outflowing tide deposited a thin layer of sand and silt over the brecciated fragments. From these observations it is evident that should the same phenomena occur on a sinking shore-line, breccias of the character so often met with by the field geologist would be formed.

On Pl. XV parts of two photographs taken by me on the occasion referred to illustrate a portion of the breccia formed on the flat in the inlet west of Noyes Point.

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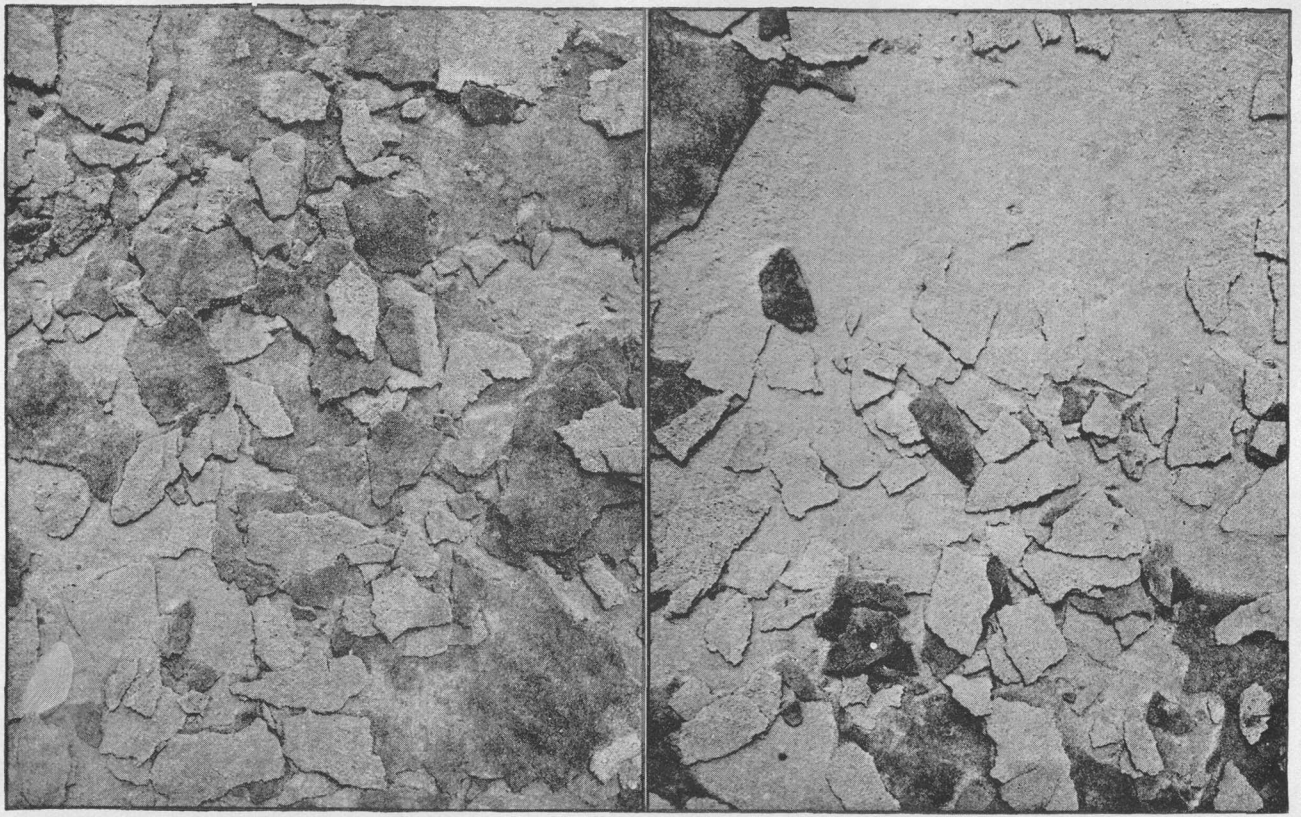
[1] Sir William Dawson says that the "only means of explaining these conglomerates [Quebec, Point Levis, Métis] seems to be the action of coast ice, which at this period appears to have been as energetic on the American shores as at the present day, and seems to have had great reefs of limestone, probably in the area of the Gulf of St. Lawrence, to act upon and to remove in large slabs and bowlders, piling these up on banks, to constitute masses of conglomerate." (Quart. Jour. Geol. Soc. London, Vol. XLIV, November, 1888, pp. 809, 810.)

[2] See articles by Willis, Thirteenth Annual Report of U. S. Geol. Surv., 1893, Pt. II, pp 217-274, and by Keith, Proc. Philos. Soc. Washington, 1892, Vol. XII, pp. 71-88, Pl. I.



BRECCIATED LAYER OF FINE SAND AND SILT PRODUCED BY THE INFLOWING TIDE BREAKING UP THE LAYER HARDENED BY SUN AND WIND ON TIDAL FLAT IN INLET WEST OF NOYES POINT, RHODE ISLAND.

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