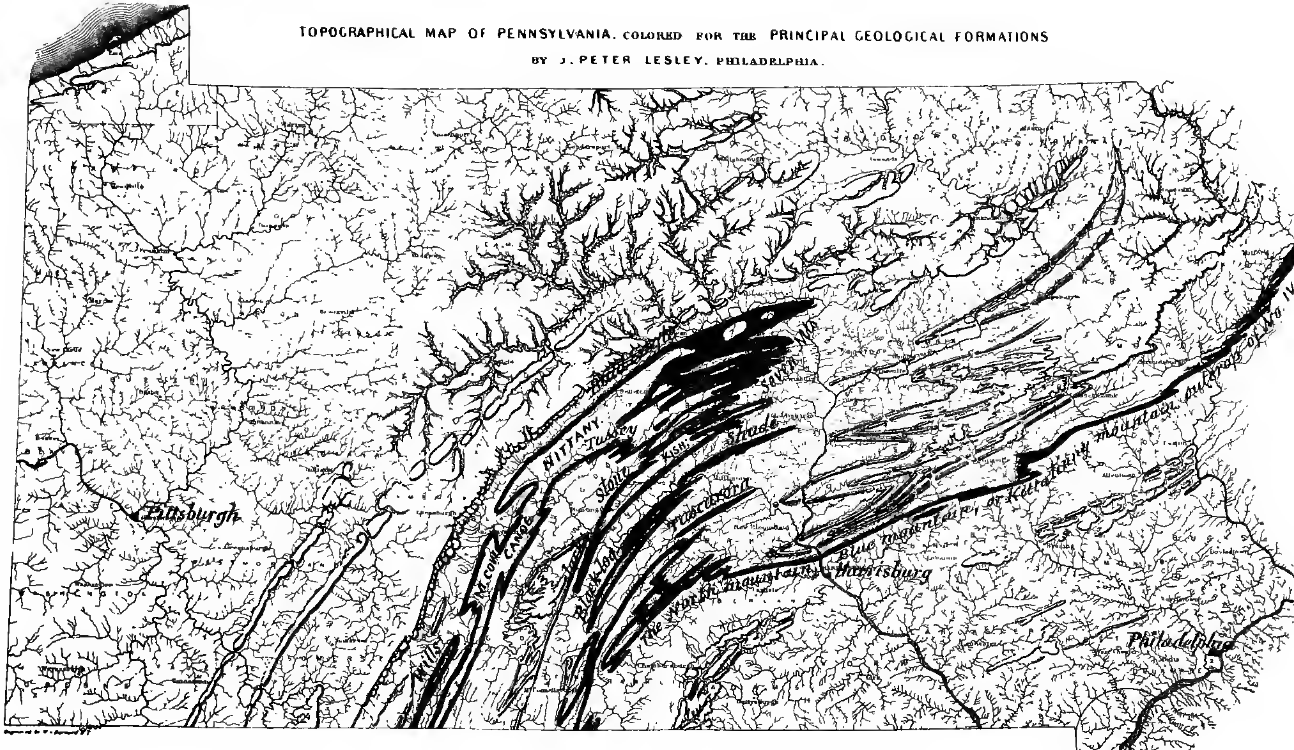
TOPOGRAPHICAL MAP OF PENNSYLVANIA, COLORED FOR THE PRINCIPAL GEOLOGICAL FORMATIONS

BY J. PETER LESLEY, PHILADELPHIA.



GEOLOGICAL SURVEY OF PENNSYLVANIA.

FINAL REPORT ORDERED BY LEGISLATURE, 1891.

A

SUMMARY DESCRIPTION

OF THE

GEOLOGY OF PENNSYLVANIA,

IN THREE VOLUMES,

WITH

A NEW GEOLOGICAL MAP OF THE STATE,
A MAP AND LIST OF BITUMINOUS MINES,
And many Page Plate Illustrations.

By J. P. LESLEY, State Geologist.

VOL. II.

DESCRIBING THE

UPPER SILURIAN AND DEVONIAN FORMATIONS.

HARRISBURG:
PUBLISHED BY THE BOARD OF COMMISSIONERS
FOR THE GEOLOGICAL SURVEY.
1892.

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LETTER OF TRANSMITTAL.

To His Excellency Governor ROBERT E. PATTISON, *Ex-officio Chairman of the Board of Commissioners of the Geological Survey of Pennsylvania:*

SIR: I have the honor to submit to your approval the Second Volume of the Final Report ordered by act of Legislature, approved in June, 1891; being a Summary of the results of the Survey from its beginning in June, 1874, to the close of its field work, June 1, 1890; Vol. I having been published and distributed to state officials, colleges, high schools, public libraries and citizens of this state, and in exchange to State geologists and geological societies in other states and in foreign countries, according to law and the rules of the Board. I expect the publication of the Third and last volume in June, 1893, together with the new Geological State Map, and the map of the Bituminous Coal Region.

The First Volume describes the most ancient deposits of our state:—The Laurentian granites, gneisses and mica schists; the Cambrian gneisses, schists and limestones; the Lower Silurian limestones and iron ores, roofing slates, and mountain sandrocks; Formations II, III and IV, in the order of advancing time and superposition.

This Second volume describes the Upper Silurian red shales, limestones and fossil iron ore beds; the glass sand quarry rocks; the black and gray shales, and the gray and red sandstones with fish beds, Formations V, VI, VII, VIII, and IX, reaching to the top of the Catskill mountain rocks, the upper limit of the Devonian system.

The Third volume will describe the Carboniferous System, with its Bituminous and Anthracite coal fields, oil and gas rocks, limestones and iron ores; the Mesozoic or New Red System; and the Drift deposits of the Ice age.

Since the publication of Vol. I, Dr. C. D. Walcott, of the U. S. Geological Survey, has communicated to me the gratifying intelligence that he has discovered two horizons of his Olenellus Fauna in the York county limestones, and two other horizons of the same fauna in the South mountain quartzites; settling thereby the Lower Cambrian age of both those formations, or parts of them; confirming the theory of a great uplift along Yellow Breeches creek in Cumberland county and the Mont Alto iron ore belt in Franklin county; and effectually disposing of the otherwise improbable identity of the South mountain quartzite with the Medina sandstone of the North mountain.

J. P. LESLEY.

1008 Clinton Street, Philadelphia,
September 17, 1892.

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CHAPTER LV.

Formation No. V. Clinton, Niagara, Salina.

Four Palæozoic ages are now passed and we enter on a fifth. Four great formations, each thousands of feet in thickness, have been deposited in the Appalachian sea and are now to be covered with a fifth, as different from the other four as they differ from each other.

We have seen the first composed chiefly of conglomerates, sandstones, and sandy shales; the second composed of magnesian limestones interbedded with pure limestone, and capped by the highly fossiliferous *Trenton limestone;* the third, composed of *Utica* black slates, and *Hudson River* gray, and roofing slates, with a few thin local limestones, and in the upper part, thin sandstone beds, indicating a change; the fourth, composed of *Oneida* conglomerate, red sandstones and shales, and massive *Medina* white sandstone beds at the top.

We are now to see the *Clinton* deposits of olive green slates, calcareous gray shales and red shales, with several sandstones of a peculiar character, and numerous thin strata of limestone, filled with small shells, and converted by the chemical action of the rainfall, for variable distances down beneath the surface, into beds of fossil iron ore. These are followed by beds of *Niagara* limestone; and these again by the deep red shales of the *Salina* salt group of New York, holding gypsum. Thus we reach the top of formation No. V; above which lie cement beds and massive limestones of the Lower Helderberg Formation of

New York, our formation No. VI, to be described in the chapter following.*

Imagined rhythmical order.

Attempts have been made by enthusiastic geologists to discover in the order of the Palæozoic formations a rhythmical arrangement, according to which sandstone, shale and limestone deposits are supposed to follow each other in triple cycles. No such order exists in nature. Formations I, II, III are sandstone, limestone, shale. Formations IV, V, VI are sandstone, shale, limestone. And it will be seen in the description of higher formations that various kinds of stuff were floated into the ancient ocean sometimes together, sometimes separately, according to no arrangement which permits of logical classification. Any order of deposits observable in one part of the ocean gives place to a different order of deposits in other parts of it; just as the great basin of the Atlantic Ocean is receiving at the present moment on its western and on its eastern side contributions of strata which have no resemblance to each other; imbedding and fossilizing for future time plants and animals of different continental species. The American side of the bed of the Atlantic is being filled up with a heterogeneous mixture from the Mississippi and Missouri regions, swept through the Gulf of Mexico and around

*The whole of formation No. V in America seems to be represented in England and Wales by the Wenlock. Among the most curious specimens of extensive limestone quarrying is that of the *Wren's nest* overlooking Dudley in Wales. Here an anticlinal dome of rocks is left standing, surrounded by deep trenches made by the quarrymen; who have taken out to a great depth the whole of two specially fine courses of the Wenlock limestone formation (Nos. V, VI). The walls between them are kept from falling over upon the central hill by huge arches left standing, like the Natural Bridge in Vinginia, or like the flying butrasses of a cathedrel. The lower reaches of the quarries are thus converted into subterranean galleries overhung by limestone bridges.—The *ball-stones* of the Wenlock limestone are described by Murchison in his Siluria as of wonderful size, some of them having a diametor of 80 feet! These have been in old time quarried separately, because they are more crystalline than the small ordinary nodules or "bumbles," of which the formation is largely composed, and better adapted for fluxing an iron furnace. See Siluria, 3d. Ed. 1859, p. 128, where he gives a very pretty landscape sketch of the outcropping gnarls and wavy layers, with three caverns left by the quarrying out of the ball-stones.

the end of Florida by the Gulf stream, to be mixed with the heterogeneous *débris* of the Atlantic States brought down by their numerous rivers, and, further north, to be still further mixed with the *debris* of Canada by the St. Lawrence; and so spread abroad over the Arctic sea. While all this is going on in our part of the Atlantic, the rivers of Europe are manufacturing and distributing other and different mixtures on that side.

The only explanation we can devise for so wonderful a phenomenon as the change from thousands of feet of sandstone No. I to thousands of feet of limestone No. II, then to thousands of feet of slate No. III, then to several thousand feet of sandstone No. IV, then to an equal thickness of shales No. V, is an explanation which although accepted as true by all geologists, no geologist however learned can clearly define in words: namely, the variable enlargement and contraction of the expanse of the ocean basin in which those deposits were made. For it is agreed on all hands, that at the mouths of rivers gravels and coarse sands are spread upon the sea bottom; further out from shore, fine sand and mud; and in the heart of the sea, limestone. But we strain our imagination in vain to invent such changes in the hydrographic maps of ancient times as will make the exactly desirable encroachment of the land upon the water in the sandstone age, and of the water upon the land in the shale or limestone age. The most powerful imagination is paralyzed by lack of facts; and especially by the impossibility of answering the question, did the separate regions of land rise out of the sea, or was the world ocean as a whole drawn away from the lands; and by that other equally difficult question, did the advance or retreat of shore lines take place suddenly or slowly? It is evident also that the flatness or precipitateness of coasts must have essentially modified every change of formation resulting from a change of water-level.

Imagine for instance the southern Atlantic ocean water-level being elevated only 400′. The whole Argentine Republic would be submerged as far west as Mendoza, and the great plains of the Orinoco, Amazon and La Plata would be under water. If this took place suddenly, the exceedingly soft fine strata of South America would immediately begin to be covered by gravel and coarse sand beds, brought down by innumerable short rivers descending the eastern slope of the Andes. The old contrast between our No. III and No. IV would be thus repeated in our own day along a belt of soundings extending north and south from Columbia to Patagonia. East of this belt would be another of the stuff; Brazil would become a great island, and begin to surround itself with a shore belt of granitic sandstone resembling our formation No. I; and the southern Atlantic, no longer receiving an enormous tribute of mud from the great South American rivers, would be left to make its deep sea limestones of another kind. The Carribean sea would feel the change also; for the equatorial current from Africa could no longer sweep into it mud of the Amazon and Orinoco as it now does; but it would feel the change only in its deeper parts; for a rise of ocean level of only 400′ against the 10,000′ wall of the Spanish Main would not appreciably alter the coast; the drainage of Venezuela would remain unchanged; its rivers would continue to pour the same material in the same abundance into the 10,000′ abyss at its foot.

Such illustrations might be taken with equal profit from any other great region of the earth's surface which presents low lying plains, backed by alpine ranges; and the profit of it springs from its teaching that the greatest changes which might take place now, or have ever taken place in any geological age of the world, must affect some regions greatly, and other regions scarcely at all; and that the furthest reach of our science of geology, in spite of its well-established principles, and its infinite treasury of well-authenticated and well-studied facts, falls far short of explaining the change in character, sometimes abrupt, sometimes gradual, between one Palæozoic formation and another. All learned disquisitions on this subject have been completely at fault; however pleasant to read they really teach nothing; and it has certainly been a mistake to summarize their vague conclusions for insertion in popular manuals and school books.

The red color of No. V.

In describing formation No. V its red color must be first mentioned; and it will assist the memory to remark here that our three great red formations have *odd* numbers, V, IX, XI. The sloping backsides and anticlinal ends of all our mountains of IV are red; the fields which are plowed on the slopes have a reddish soil; and along the little valleys at the foot of the mountains runs the deep red outcrop belt of *Lower Salina* (*Bloomsburg*) *red shale.* The quantity of iron salts infusing the water must have been unusally great; for not only the numerous fossil-iron-ore beds in the formation but chemical analyses show that the charge of iron is inherent in its constitution; the exhibition of so strong a color being however due to the action of the weather, peroxidizing the protoxide. The protoxide of iron is mostly in combination with carbonate of lime as a triple compound, carbonate of the protoxide of iron and lime. The iron ore beds, when followed far enough beneath drainage level, show by chemical analysis that this is their constitution. Above drainage level their carbonate of lime has been dissolved and carried off; their carbonate of iron has received a double charge of oxygen, and remains behind as red-hematite iron ore. Of this more will be said in describing the ore beds.

In the last chapter the *Lower Medina* or middle member of No. IV was described as a mass of alternate red sandstones and red shales. Many of the beds of No. V are sufficiently like the *Middle Medina* beds to suggest that they are virtually a continuation of them; an invasion of great quantities of white sand having only interrupted the progress of the red deposits. But no limestone or iron ore beds have been noticed in middle No. IV; therefore we have in the deposits of No. V a new element, lime. From whatever source this lime was derived it began to come into the sea slowly and in moderate quantities; increasing in quantity and frequency; and finally, as formation No. VI, it became the predominant element of the deposits.

The thickness of No. V.

The thickness of No. V varies in different parts of the State; thinning away southward towards the Potomac and eastward to the Delaware river; and disappearing entirely on the Hudson. At the Schuylkill Water Gap, where its top is concealed, the beds visible measure 2606′; at the Lehigh Water Gap the measurement 1275′ is uncertain.* At the Delaware Water Gap it is at least 1685′† (G6, p. 85). At the Susquehanna Gap it is very thin, which may be explained perhaps by the slip of the great overturn; for in other parts of Perry county it is about 2500′. At Danville and Bloomsburg, in Montour county, on the north branch of the Susquehanna, it is 2000′; at Lewistown on the Juniata, 2070′; in Logan's Gap 2075′; at McVeytown about 2200′; at Mount Union only 1136′; at Orbisonia in southern Huntingdon, 1110′; in Fulton and Bedford say 900′; in Blair county doubtfully 1328′; in northern Huntington it seems to be about 2500′; in Centre county, back of the Bald Eagle Mountain, at Lock Haven, it was measured 1080′; and in southern Lycoming it is estimated to be between 2000′ and 2500′.

These measurements were made with more or less exactitude, instrumentally and otherwise, at various times, by different assistant geologists of the state survey, whose detailed sections showing the order and size of the beds will be given further on.

The assumed limits of No. V.

In all cases where measurements were made of the whole formation its top was assumed to be the *Water lime hydraulic cement beds* of No. VI, and its bottom the last solid white sandstone bed of No. IV; but the contact between IV and V is seldom seen, as it occurs two-thirds of the way up the slope of the mountains of IV, in the woods which

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* Chance's measurement. Prof. H. D. Rogers gives V a thickness of 1765′, G. P. Vol. I. 1858, p. 131.

† Dr. Chance's measure of the *visible* beds only above which is a space of Cherry Run Valley un-exposed rocks estimated at 740′. See G6, page 83.

remain and will probably always remain covering the rock-slid surface. In the gaps through the mountains the contact is usually partially concealed by stone slides. In like manner the upper limit of the formation, or its contact with No. VI, is indefinite for another reason, namely, that there is not everywhere an abrupt transition; for the calcareous top layers of V pass into the bottom calcareous layers of VI; so that it is not always easy to say whether the beds of a locality belong properly to V or to VI. For the cement layers of VI are irregular and were deposited somewhat earlier or later in different districts of the state. Errors in measurement also arise from the rolls and wrinkles to which the soft strata of No. V are especially subject, as may be seen in the railroad cutting along the Juniata at Perrysville, and at the end of the Long Narrows opposite Lewistown, and elsewhere. But in spite of these irregularities of dip some of the measurements given above may be accepted with confidence as very exact; especially the measurement in Logan Gap, north of Lewistown, and at the Delaware Water Gap; although the sum total here and at the Schuylkill Water Gap is less than it ought to be because the uppermost beds of red shale are concealed.*

We may accept a general thickness of about 2000′ for No. V over middle Pennsylvania; and we may partly account for the extra thickness in some localities by the packing or bunching of the formation under the influence of that pressure which has thrown it into innumerable small arches and troughs. But whatever variations of thickness the whole formation has been subjected to in many places its numerous sub-divisions, which will be described directly, preserve everywhere in a remarkable degree their individual character. But what is most remarkable, while these sub-divisions preserve their distinguishing characters, each of them exhibits great differences of thickness when followed from district to district.†

*Along the Little Schuylkill, north of Port Clinton, the formation is beautifully exhibited in a series of ten anticlinal arches.

†This is especially true of those above the *Ore sandrock*. These below it have been thought to vary in an extraordinary degree; but the error has been committed of supposing the *Iron Sandstone* one and the same everywhere; whereas there are at least two and perhaps more.

Variation of thickness.

Thus, beginning at the bottom, (1) the *lower olive slate* varies from 100′ to 700′. (2) The *iron sandstone* over it varies from 5 to 50′. (3) The *upper olive slate* varies from 50′ to 250′. (4) The *lower lime shale* varies from 100′ to 250′. (5) The *ore sandstone* varies from 10′ to 100′. (6) The *upper lime shale* varies from 50′ to 250′. (7) The *variegated red marl* varies from 100′ to 450′. (8) The *gray marl* varies from 500′ to 1200′. (9) The uppermost flaggy *blue limestones* (which may be placed either in No. V or in No. VI at the option of the geologist) vary from 50′ to 350′. With such variations staring us in the face how absurd and how deceiving it would be to construct a general section of No. V for a text-book.

For, in the first place, while the sum of the *averages* of these thicknesses added together make 2277′ and this agrees well enough with the actual measurements given in the preceding paragraph at localities where the formation is at its thickest, the figures would be a false guide to the field worker at any given point and especially where the formation is thin.

Secondly, the sub-divisions of the formation exhibit variations of thickness in different directions quite independently of each other, and according to no rule that has yet been discovered. Therefore, in describing No. V throughout Pennsylvania no general section of it can be of practical utility. It must be described as it exhibits itself in each district. Fortunately it has been studied critically at so many localities that its description becomes an easy although a tedious task. The fossil ore beds in its lower half have been such a source of wealth at Bloomsburg and Danville, east of the Susquehanna; on Penn's creek in Union; at Frankstown in Blair; in Dutch Corner and Bloody Run in Bedford; at Orbisonia in Huntingdon; and along the Juniata river between Mount Union and Logan; at Mifflintown in Juniata; and at Millerstown in Perry; that the formation containing these ore beds is perfectly well understood.

From the Susquehanna to the Delaware, however, No. V is destitute of these iron ore beds and therefore its character is only known at the Water Gaps; and that but partially, and in its larger subdivisions.

The outcrop belts of V furnish water channels.

In tracing the red outcrop belt of No. V throughout the State it will be noticed that the principal rivers and creeks have excavated their channels in it and thereby more or less concealed it. Flat Kill in New Jersey flows 20 miles down a synclinal basin of V to the Walpack Bend of the Delaware in Monroe county. For the next 12 miles the Delaware river occupies the outcrop and then cuts through the whole formation at the Water Gap. The next 12 miles is occupied by Cherry creek; and the next 15 miles by Aquanchicola creek, which heads at the Wind Gap and enters the Lehigh river at the Lehigh water gap. Here a beautiful conical eddy-hill 300′ high is left standing picturesquely behind the gap.

In like manner the Juniata river flows 10 miles in the soft rocks of V around the east end and along the north foot of Tuscarora mountain above Millerstown. The Juniata flows for 30 miles in the soft rocks of V across the numerous small anticlinal at Mifflintown; around the end of Blue ridge; through the wild synclinal gorge of the Long Narrows between Blue ridge and Shade mountain; and along the Lewistown valley to the Ox-Bow bend at Newton Hamilton.

The West Branch of the Susquehanna flows along the outcrop of V from Williamsport to Muncy, 10 miles; and then across its numerous anticlinal and synclinal outcrops 25 miles to Sunbury.

Thus, while in some parts of the state the water courses conceal the formation, in other parts their banks afford a hundred opportunities for exhibiting it to the critical examination of geologists, We will take up its description at the places where it has been instrumentally studied.*

*The Clinton formation in Ohio is a thin stratum of porous limestone seldom more than 15′ thick. Were it thicker it would probably have had as many caves in it as has the carboniferous limestone of Kentucky, so famous for its dens of robbers and illicit distillers of whisky. No caves are known

At the Delaware Water Gap.

Strata concealed by Cherry run valley,			740′
Upper red shale,	155′	1685′	
Variegated shales and ore sandstone,			
Lower red shales,	740		
Lower olive shales,	340′		2425′

These measurements can be relied upon as the results of an instrumental topographical survey by Dr. Chance in 1874. A map on a scale of 800′ to 1 inch, with contour lines 20′ apart and datum level at the river surface 297′ above tide, was published in Report G6; with two carefully constructed vertical cross sections, one on each side of the river. (See plates 78, 80, on pages 634, 668. It will be noticed that the *Lower olive shale* forms a decided terrace on the mountain, the brow of which terrace is made by hard beds in the *Lower red shale* above. It will be noticed that at the bottom, in the middle, and at the top of the *Variegated shales* are three groups of sandy strata; the middle one making a decided mark in the topography. This middle sandstone, called the *Ore sandstone*, which will be better described in middle Pennsylvania, makes the "Table rock" at the Delaware Water Gap hotels, being preserved at the bottom of a gentle synclinal. Only 155′ of the lower part of the *Upper red shale* is visible on the west side of the river, the rest of it being concealed by the bed of Cherry run valley to the west, and the bed of the Delaware river to the east.

In Monroe county the actual contact of the top red shale bed of No. V with the bottom limestone bed of VI has been noticed at only a single locality in Monroe county, namely, in the river bluff opposite the upper end of Poxono island. Here 75′ of dull red shale (spotted with green) supports the limestone at the top of the bluff; the red shale going down into the water; much lower beds of red shale appearing on the southern New Jersey bank of the river.

in No. III, the Cincinnati group. But in Preble county there is a Clinton cave, beginning with a sinkhole 6′ or 8′ deep, continued as a narrow descending gallery, opening into a small chamber with a floor of sticky mud. Traditions say that there were several mouths and that bones of animals were found. (J. F. James, Jour. Cin. Soc. Nat. Hist., May, 1890.) In Pennsylvania no caves in any rocks of V have been reported.

No fossils in the red beds of V.

Not a single fossil of any description has been seen in these rocks. Were there any fossiliferous beds in it some of them at least would have been converted into beds of fossil ore, as in middle Pennsylvania. The iron remains therefore unconcentrated, and is disseminated throughout the formation. The amount of iron must be enormous; for an analysis of a specimen of red shale taken from the bluff 50′ below the limestone reads: Silica, 58.2; alumina, 19.9; sesquioxide of iron, 8.2; lime, 0.5; magnesia,* 2.6; phosphorous, 0.038; water, 0.37.

There is no reason for thinking that the charge of iron found in this specimen differs much, if any, from the general charge in the whole formation; so that the metallic iron in every hundred feet of the red beds would make a solid bed of metallic iron more than 2 feet thick; hence it is not for lack of iron in the formation that no beds of fossil iron ore range behind the Kittatinny mountain through Monroe, Carbon and Schuylkill counties to the Susquehanna river; but it is from a lack of beds of fossil shells to decompose, concentrate, and precipitate the iron as red hematite (J. C. White, G 6, 149).†

At the Lehigh Water Gap.

Strata concealed in the Aquanchicola valley, unknown.

Upper red shale,	650′	1275′
Variegated red shale,	90′	
Upper olive lime shale,	120′	
Ore sandstone,	125′	
Lower red and olive shales,	290′	

These measurements are the result of an instrumental topographical survey of the Lehigh Water Gap, with a contour line map, and vertical cross section, made by Dr. Chance in 1875.

*This greater quantity of magnesia and the very small quantity of lime is the notable feature of this analysis.

†*Zinc blende.* Traces of this mineral may be seen in the red shales immediately under the solid limestone beds of No. VI, at J. Turn's, opposite the upper end of Poxono island, in the Delaware river, Monroe county. Scattered patches of the *green carbonate of copper* are also seen on these shales. (G_6, p. 217.)

It will be noticed that the *Medina upper sandstone* top of No. IV here makes the crest of the mountain. For half way down upon the slope the *Clinton lower red and olive shale* crops out. A slight change of dip however has preserved as a delicate terrace a fragment of the Ore sandstone. The main outcrop of the *Ore sandstone* runs along the mountain two-thirds of the way down the slope, dipping 45° north, and gradually plunging more steeply into the river channel at the entrance to the gap. The northern foot-slope of the mountain is made by what is really the middle of the great formation; and along this foot-slope runs a decided terrace of hard beds in the red shale. These hard beds (dipping north, 70°) have preserved the picturesque conical eddy-hill at the entrance to the gap, cut off from the terrace by the Aquanchicola creek, and standing between the creek and the river. As the rocks of No. VI in Stony ridge opposite stand vertical it is impossible to measure the amount of red shale concealed in the valley. Extraordinary contortions, closely complicated synclinal and anticlinal rolls, run along Stony ridge, as shown in pl. 4 of G 6. It looks as if the whole formation No. V has slid down northward upon the top surface of No. IV crumpling its own upper soft red shale parts.

The horizontal distance across the last visible red shale in the conical hill to the cement beds of VI in Stony ridge is 3000′, all of which distance must be occupied by soft shale. The actual thickness of red shale however cannot be ascertained, because it is impossible to know the variations of dip. An estimate of a thousand feet would probable be considerably below the mark, and this added to the 1275′ of the section would make 2275′. It is more probable that 2000′ of concealed shale exists; but this would make No. V 3275′ thick, and give to it at the Lehigh Water Gap a size greater than anywhere else in the State.

The actual contact of V and VI is visible at the base of Stony ridge, where 150′ of *Upper Salina* shales rise vertical under 70′ of *Cement beds*. This is particularly interesting, since we have seen that opposite Poxono island in the Delaware river the lowest massive limestone rests upon a great mass of red shale probably *Lower Salina;** and from this fact one would conclude that, in the interval of 35 miles, the Middle and Upper Salina have thinned away eastward to nothing; which agrees with the general thinning away of the whole formation No. V still further eastward to nothing at the Hudson river. But on the other hand it will be seen further on that on the North Branch of the Susquehanna there are red beds in the *Middle Salina group.*

No. V at Port Jervis.

Before going west to the Schuylkill, it will serve to illustrate this eastward thinning, to notice the exhibition of No. V at Port Jervis at the bend of the Delaware, 35 miles northeast of the Delaware Water Gap, although no section can be given of the formations anywhere along the river, which flows over it. Nearpass' quarry, on Mill brook, in New Jersey, is in a bluff of No. VI. Here are 200′ of concealed strata beneath the supposed beds of No. VI. The whole formation No. V is here entirely concealed beneath a buried valley 500 yards wide; a dip of 25° seen at the top of the bluff would give No. V a thickness of only 600′ (G6,75).

No. V at the Schuylkill Water Gap.

At Port Clinton, the upper beds of V, that is *Middle* and *Upper Salina*, and perhaps part of the *Lower Salina*, have been eroded in the first synclinal behind the gap, as seen in Dr. Chance's vertical cross section (Pl. LII) constructed on the basis of his instrumental contour line map of the gap surveyed in 1874. The rest of the section is as follows:—

Upper red shale,	750′	2606′
Upper red shale and sandstone,	630′	
Upper olive shales,	680′	
Ore sandstone,	96′	
Lower olive shale,	450′	

It is safe perhaps to add several hundred feet for the eroded top rocks, which would make the whole thickness of

*Under the Bossardville limestone lie 200′ of Poxono shales; under these massive Poxono limestone; under this 5′ buff shales, and then comes the great mass of Lower Salina red shale. (See G6, p. 146, 147.) This will be discussed in the next chapter.

No. V about 3000′. The distance between the Lehigh and Schuylkill Water Gaps is 25 miles; and it is certain that the formation maintains, at least for this distance along the north slope of the mountain and the valley at its foot, this great thickness.

The mountain at the Schuylkill gap has its crest made by the vertical *Oneida conglomerate;* and a bold terrace on its north slope is made by *Medina sandstone.* From the brow of the terrace down to the Schuylkill river at its foot the slope is steep and rocky, and is composed of the *Clinton Lower* and *Upper olive shales* 480′ and 680′ thick respectively. Between them, half-way down the slope runs the outcrop of the *Iron sandstone*, 96′ thick. On the north side of the Schuylkill, and exposed transversely in the bank of the Little Schuylkill, are the *Salina red shales*, 1380′ visible; the lower 630′ being mixed with red sandstones. The crush in the center of the synclinal which crosses the Little Schuykill is shown by a double flexure of the soft rocks.

In 1838 I found fragments of *block iron ore* among the fallen *débris* on the south bank of the bend of the Little Schuylkill opposite Port Clinton, where it cuts into the foot of the mountain to enter the main river; but the mother bed from which the fragment fell was not discovered for many years afterwards, and when opened was found to be worthless; but it represents in eastern Pennsylvania the *block ore* which will be described in middle Pennsylvania, especially in the neighborhood of Huntingdon, where it is a thick stratum of hard sandy ore enclosing a middle bed of soft good ore.

At the Swatara Water Gap, north of Pinegrove, 30 miles west of the Schuylkill, in Lebanon county, formation No. V has never been properly examined. In 1839 I could see nothing; for the gap and the valley behind the mountain was a forest-covered wilderness. A farmer whom I met tried to dissuade me from going through the gap because as he remarked, "the country has never been finished;" and by some oversight the locality has been neglected by the Geological Survey up to the present time; or rather my original plan of having every gap in the state instrumentally surveyed and mapped in contour lines, for the study of the topographical features, and for the construction of reliable transverse vertical sections of the formations, could not be fully carried out for want of means, because of the incessant demands made upon the survey for work at other points of more money value and business importance. We greatly need however a Swatara Gap cross section, similar to those obtained at the Delaware, Lehigh and Schuylkill Gaps; especially in view of the question why formation No. V makes so poor a show at the Susquehanna Gap. In describing No. IV I have anticipated in part this question.

No. V at the Susquehanna Water Gap.

At the Susquehanna Gap four miles north of Harrisburg, the *Lower olive shale* is less than 200′; but the *Iron sandstone* is 80′. There is no appearance of the *Upper olive shales* and the whole *Lime shale group* is represented by 50′; over which lie only 400′ of *Lower Salina red shale.* The *Middle* and *Upper Salina* are wanting; also the limestone formation No. VI, the *Oriskany* sandstone No. VII, the whole of the *Marcellus*, and part of the *Hamilton* (the two lower formations of No. VIII).

Professor Claypole's theory* that there was no original deposition of these formations at this particular locality and its vicinity, extending for some miles east and west of the river, for the reason that there was dry land here in Silurian and Lower Devonian times, may be acceptable to most geologists as being the easiest way to account for their absence. But it is a very remarkable fact that this state of things occurs only here; that is, just at the place where the greatest uplift and overthrow of the whole body of Palæozoic rocks occurs; the strata being thrown over on their faces 20° beyond the vertical towards the north; and it would be a strange thing indeed if in the plication of such an immense fold there should not have happened such a sliding of one formation upon another as to greatly

*See Report F2. 1885, pp. 37 and 393.

change their respective thickness and perhaps to shift part of them in such a way that they would disappear from a cross section made at the present drainage level. To accept the hypothesis of dry land at any stage of the Palæozoic series until we reach the Coal measures would greatly modify our views of subsidence and deposition. If it be accepted in this instance we must imagine that, while the Appalachian sea continued deep everywhere else, it had here been filled up to its surface in the form of an island, or a long point of land projecting from some continental area in the southeast; for, the missing formations at the Susquehanna gap appear in full force up the river and to the west; and we have seen that No. V at least is very thick not far to the eastward. How far eastward the thickening of No. V begins and to what extent and at what rate, we will not know until a special instrumental survey is made of the Swatara Water Gap, and of the outcrop of No. V along the north flank of the Blue mountain east and west of that gap.

Chapter LVI.

No. V on the North Branch Susquehanna.

Formation No. V does not appear at the present surface anywhere in eastern Pennsylvania between the Blue mountain and the North Branch of the Susquehanna except on a small anticlinal crossing the Susquehanna at Georgetown in southern Northumberland; and it is very deeply buried beneath the anthracite coal regions. But in the angle between the North Branch and West Branch Susquehanna river in Columbia, Montour and northern Northumberland counties, it is brought up by the great anticlinal of Montour's ridge; and fine sections of it are exhibited in the two transverse gaps at Bloomsburg and Danville. It occupies almost the whole surface country east of Milton and Watsonburg; and it is again brought to the surface by the Bald Eagle anticlinal and finely exposed in the river bluffs at Muncy.

It will be sufficient to describe it as it has been sectioned by Professor I. C. White at Bloomsburg and Danville; where also it was many years ago studied with exact care and elaborately described by Professor Rogers in his final report, Geol. Pa. 1858, Vol. I, pages 440–450, and Vol. II, pages 728 to 732.

No. V in Montour's Ridge.

Montour Ridge is the only mountain of No. V in the whole State; that is, the only mountain whose crest as well as flanks are composed of *Clinton* rocks. It is an anticlinal mountain about 500′ high, 25 miles long, perfectly straight, and tapering at both ends to a point sloping gradually and fading into the plain. Its shape betrays its structure. It is an anticlinal arch, beautifully symmetrical, with horizontal beds along its top, curving downward and falling away

XCIX

No. V Clinton (a), Niagara (b), Salina (Onondaga, c)
Fossil iron ore beds in Montours ridge.

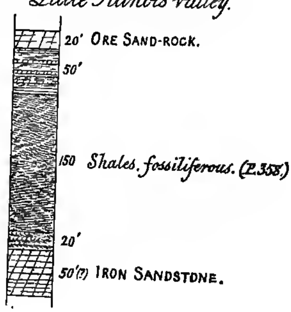
FIG. 81.—Section of Montour Ridge at Danville.

FIG. 82.—Section of Montour Ridge at Hemlock Creek.

FIG. 83.—Section of Montour Ridge at Fishing Creek.

Plate XXXI.

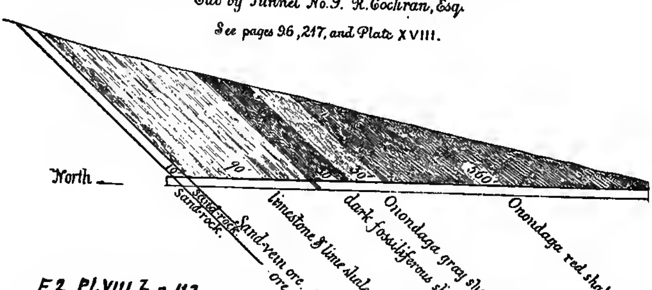
Fig. 2. The Clinton beds of the Little Illinois valley.



Section in Slaughterbeck hill, Greenwood township.

Cut by Tunnel No. 9. R. Cochran, Esq.

See pages 96, 217, and Plate XVIII.

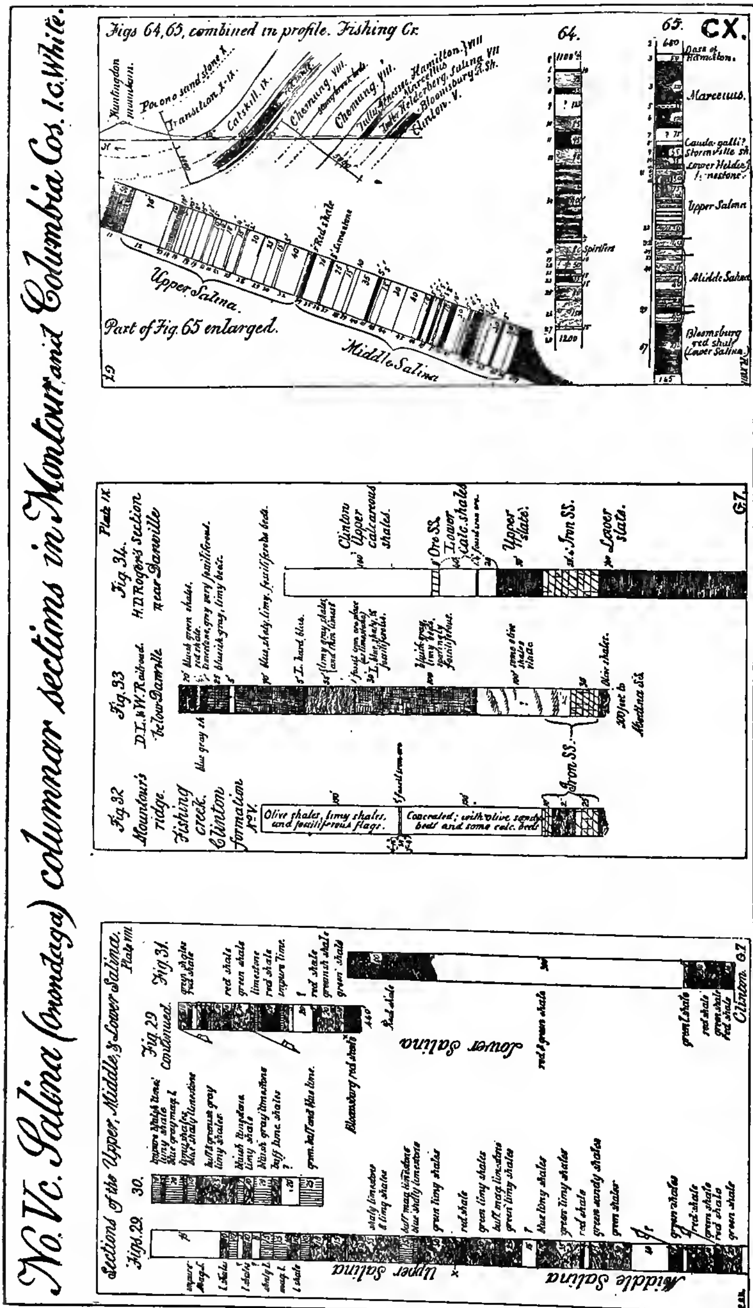


F2. Pl. VIII to p. 112

gently on each side, northward and southward, to dips of 20° to 30° at water level. See Figs. in Geol. Pa., Vol. I, 441; reproduced in Plate XCIX on the preceding page.

Such is its general description; but when studied carefully the arch is seen to be in one part of its course double, where two anticlinal arches lap past each other. The lap takes place near the east end of the range, and is exhibited at Bloomsburg by a distinct double arch as shown in Fig. 2. Here the ridge is cut through to its base by Fishing Creek; and by Hemlock Creek. At Danville (10 miles west) it is cut through by Mahoning Creek. The three figures represent the three sections exhibited in these three gaps. The ridge, although only 500′ high at Danville, and 400′ at Bloomsburg, is more than a mile wide, measured from the red shale waterway at its southern foot to the red shale waterway at its northern foot. The top of the ridge has been weathered nearly flat, so as to expose the *Clinton olive shales* for a breadth of 2000′. On each side of this flat top runs a terrace the whole length of the mountain; a terrace produced by the outcrop of the *Iron sandstone*. A thousand feet further down the slopes a second terrace is made by the outcrop of the *Ore sandstone*. In the Danville gap an arch of *fossil ore* is seen in the body of the *Lower olive shales*, about 400′ geologically above the *Medina sandstone*, which however, nowhere shows at the surface, even on the mountain top, except only at one point, two miles below Danville, where a ravine deeper than common has cut down into the top beds of No. IV.

At this point, where a bend of the river has cut sideways into the ridge, we get a good section of the *Upper, Middle and Lower Salina*. These upper sub-divisons of No. V, are even better exhibited where Fishing Creek issues from the gap back of Bloomsburg. They are also well exhibited on the north side of the mountain, where Fishing and Little Fishing creeks come together, two miles back of Bloomsburg; the main creek meandering for 3 miles (from Light Street to the gap) along their outcrops, affording in fact the only complete section of the whole series in this district of the State (G7, 101).


No. Vc. Salina (Onondaga) columnar sections in Montour and Columbia Cos. I. C. White.
Figs 64, 65, combined in profile. Fishing Cr.
CX.
Part of Fig. 65 enlarged.
Upper Salina.
Middle Salina.
Fig. 32 Montour's ridge. Fishing creek. Clinton formation No. V.
Fig. 33 D. L. & W. Railroad below Danville
Fig. 34. H. D. Rogers's section near Danville
Sections of the Upper, Middle, & Lower Salina.
Figs. 29. 30.
Fig. 29 Continued.
Fig. 31.
Lower Salina
Clinton.

Section of No. V along Big Fishing Creek.

Here Prof. I. C. White made elaborate sections of the three sub-divisons of the *Salina formation*, *Vc*, which were published in his report of the region, G7, and on his plates 8, 9 and 18. These are reproduced on a reduced scale on plate CX, page 740 above. The text of his principal section is as follows:—

Vc. Upper Salina group, 329′.

1. Pale buff and greenish magnesian limestone, quite impure,	75′
2. Shales, limy and pale green,	10′
3. Limestone, impure, pale green,	10′
4. Concealed,	5′
5. Limestone, and limy shales,	10′
6. Concealed,	8′
7. Buffish shaly limestone,	15′
8. Pale green, magnesian limestone,	15′
9. Bluish gray limestone, impure,	5′
10. Buffish, limy shales,	10′
11. Blue, shaly limestone,	10′
12. Buff and greenish shales.	18′
13. Bluish gray, impure limestone,	4′
14. Pale green, limy shales,	15′
15. Bluish gray limestone, rather pure,	2′
16. Buffish, limy shales,	2′
17. Pale green, shaly limestone, and limy shales,	55′
18. Buffish, magnesian limestone,	15′
19. Blue, shaly limestone,	5′
20. Greenish, limy shales,	40′

Vc. Middle Salina group, 407′.

21. Pale green, limy shale with *purplish* cast,	7
22. *Red shale*, containing 10 to 12 per cent. of iron,	5′
23. Shales, limy, pale green,	30′
24. Buff and bluish, magnesian limestone,	5′
25. Pale green, limy shales,	25′
26. Concealed,	15′
27. Bluish, limy shales,	10′
28. Greenish, limy shales,	35′
29. *Red shale*,	5′
30. Concealed,	5′
31. Greenish gray, sandy shales,	15′
32. Pale green shales,	30′
33. Concealed,	40
34. Green shales,	10′
35. *Red shale*,	5
36. Concealed,	5′

37. Green shale, ... 5'
38. *Red shale*, ... 5'
39. Varigated shale (red and green), ... 5
40. Limestone, bluish gray, good, ... 3'
41. Green shale, ... 10
42. *Red shale*, ... 10
43. Green shale, ... 20'
44. Limy shale, ... 5
45. Limestone, gray, rather pure, ... 4
46. Green shale, ... 3
47. *Red shale*, ... 20'
48. Limestone, gray, impure, ... 5'
49. Concealed, ... 5'
50. Green shale, ... 5'
51. Concealed, ... 20'
52. *Red shale*, ... 5'
53. Greenish shales, containing thin, bluish gray, impure limestones, ... 20'
54. Green shale, ... 10'

Vc. Lower Salina group, 440'.

55. *Bloomsburg red shale*, a series of dark red shales, somewhat sandy, and blotched with a few thin layers of bright green, visible in the vicinity of Bloomsburg, for a thickness of about 440'.

Va. Clinton; 713' visible.

56. Olive brown shales, limy beds, and flaggy sandstones fossiliferous, ... 150
57. *Fossil iron ore*, { *Ore*, "big vein," . 10' to 12 / Limy and sandy shale, 2' 0" / *Ore*, "little vein," . . 3" to 4" } 3'
58. Concealed and olive sandy beds together with some calcareous bands, ... 150'
59. *Iron sandstone*, ... —
  (*a*) Very hard dark red or reddish-brown sandstone containing 10–15 per cent. of iron, ... 10'
  (*b*) Shales, yellowish-greenish with streaks of red, 25'
  (*c*) Dark brown sandstone containing thin streaks of lean *Iron ore* and some shales, ... 25'
  } 60
60. Pale yellowish-green and olive shales to crest of Berwick axis, in the gap of Fishing creek, at water level, . . 350'

Upper limit of the Salina as assumed by I. C. White.

The upper limestones of the *Bossardville group* (lowest member of No. VI) are abruptly superposed on the buff colored, gray, or pale green, magnesian, and clayey limestones at the top of the section, which of course assume various aspects at other places in middle Pennsylvania and were considered a part of No. VI by members of the First Survey; and their representatives have probably been included in No. VI in some reports of the Second Survey. I have already remarked, that structural geologists will consider it optional whether to place them at the top of V or at the bottom of VI; but Professor White in making the Fishing Creek section regarded them as the Pennsylvania representatives of the uppermost of the three divisions of the Salina formation of New York. While the purer limestones of VI resist the weather and furnish fine exposures these beds decompose readily and are nearly always buried beneath fallen matter and soil in the valleys along their strike. Fortunately Fishing creek at its bend to enter the gap washes its western shore and exhibits the north dipping Salina beds of the section; and they can be studied and measured along the new road through the gap in a continuous series of rock cuts.

The Upper Salina group extends from the solid limestone down (329′) to the first red bed. The Middle Salina group (407′) is confined to the alternate red, olive and gray shales. The Lower Salina (440′) is almost wholly made up of beds of red shale (color strongly pronounced), somewhat sandy and blotched with green. This is of course an artificial subdivision, and it is impossible to answer for its reappearance in detail in any other locality; for the red color of rocks is a variable element. But it is no more variable than any other element in a description of a series of deposits; nor does palæontology help us in this matter; for the distribution of fossil shells is quite as variable; each deposit of shales being quite local; fading away in all directions from a central point, and replaced by a similar bed in neighboring districts at a higher or lower level. Moreover, the animal forms were related closely to the kind of mud or sand they lived in, and to the condition of the water at the time of their living. Red beds are usually non-fossiliferous; the fossils apparently clinging to the gray rocks; and it is no proof that a stratum at one spot is the same as a stratum at another spot because the same fossils are found in both. The palæontological world is now fully aware of this important truth and depends more than it used to do upon the continuous tracing of fossiliferous beds along outcrops for their sure identification. If this be so in the case of localities not far distant from each other how much stronger is the application of the truth to the presumed identification of subdivisions of a formation which only appears in middle Pennsylvania and in central New York, that is, along outcrops 150 miles distant from each other. The division of V into Salina, Niagara, and Clinton, and the subdivision of the Salina into Upper, Middle and Lower in Montour's ridge to make it agree with its triple sub-division in western New York, must be regarded simply as a convenience. And this appears the more plainly from the fact, first, that the Niagara formation of New York cannot be unmistakably recognized in the above section; nor in fact anywhere in Pennsylvania, except perhaps at an extreme eastern point in Pike county; and, secondly, that the Upper Salina of New York is a gypsum formation, no gypsum being seen beneath No. VI anywhere in Pennsylvania.

Gypseous character of the Salina.

Although gypsum in beds, or in hopper-shaped cavities, does not appear, it may exist in small disseminated particles; since the upper layers of our section (329′) has got from the quarrymen the local name of *sulphur stone* from the fact that in former attempts to burn them into lime they gave off an intolerable odor.

The Salina of New York is barren of fossils, and in this respect, as well as by the color and constitution of its layers, resembles the upper part of our section. *Not a single fossil has been found in the Upper Salina of the Montour ridge district.* Some of the beds are occasionally pure enough to burn, but only one quarry (Russell's near Danville) has been worked in any of them, and that for mixed flux in an iron furnace. A quarry was attempted between Lime Ridge and Espy but no layers proper for lime burning were found.

The section at Russell's quarry showing the uppermost

185′ of the layers is here added to show their variations at different localities (G7, p. 102, Fig. 30).

Upper Salina at Russell's quarry, (G7, f. 31.)

Bossardville limestone, base of Lower Helderberg. No. VI.

1.	Bluish green, impure limestones containing small irregular cavities lined with crystals of calcite,	10′	185′
2.	Limy shales,	5′	
3.	Hard, bluish gray, magnesian limestones,	20′	
4.	Drab limy shales,	3′	
5.	Limestone, blue and shaly,	10′	
6.	Buffish, and greenish gray, limy shales,	45′	
7.	Bluish limestone, banded with thin blue and gray layers,	7′	
8.	Limy shales, gray and greenish,	10′	
9.	Bluish gray limestone, once quarried, not very impure,	20′	
10.	Buffish limy shales,	10	
11.	Concealed,	20′	
12.	Pale green, buffish, and bluish limestone down to the bottom of the exposure,	25′	

The Middle Salina group is sufficiently described in the section, to show that it agrees in character with the *Variegated Group* of the New York geologists. Some of its lower limestone beds, blue or bluish-gray but non-fossiliferous, might make good lime, but none of them seem to have been quarried in this district.

The Lower Salina has received the name of *Bloomsburg red shale* because so well exposed in the Iron company's railroad cuts at the north line of the town. Here nearly or quite its full thickness is seen; but as the lower part of the Middle Salina is here concealed, it is possible that 10′ or 20′ of red shales may also be concealed; not more than that however, because a few Middle Salina thin buff lime layers begin to appear at that distance above the red shale. The whole mass of red shale is not elsewhere completely exposed in the district; and it may in some places reach a thickness of 500′. It is usually rather sandy and stands in bluffs or cliffs along the streams. The color is a deep dull red with some of the beds of brighter red. Thin layers of apple green shale are interlaminated with the red. Often for several feet in thickness no stratification whatever appears, but the whole mass weathers away by breaking across the bed into small, irregular chips, which give the cliffs a peculiar roughened aspect. The only fossil in the whole group was a *Lingula* found by Professor White near Chulosky furnace, near the eastern line of Northumberland county, where the following section was made:

Lower Salina near Chulosky Furnace, (*G 7, f. 31.*)

1. *Red shale*, blotched with green,	60′	416′
2. Variegated (red and green) shale containing *Lingula sp.?* in large numbers,	1′	
3. *Red shale*, containing a few thin streaks of green,	300′	
4. Greenish, limy shales,	5′	
5. *Red shale*,	30′	
6. Green shale,	5′	
7. *Red shale*,	15′	

The top of this section is wanting, but some green shale 25′ higher would increase the sum total to 441′; and if 20′ of bluish green shale and another red bed 4′ thick beneath the bottom of the section were added, the total thickness would be 465′; but these last have been placed in the upper sub-division of the Clinton.

The Bloomsburg red shale extends so universally throughout middle Pennsylvania, and agrees so well in character with the Lower Salina of New York that they must be the same formation.

The general softness of all the Salina strata confines their outcrops to the valleys and low lands. The soil which they make is the most fertile in this part of the State, on account of the large quantity of lime set free by the decomposition of the marly shales.

The Niagara formation, Vb.

The Niagara formation of New York cannot be recognized in this district as a distinct formation. Although characteristic Niagara fossils have been collected along outcrops from rocks which underlie the Bloomsburg red shale, in several parts of the State, they are mingled with characteristic Clinton fossils. They will be mentioned further on in describing No. V in Perry county. The great *Niagara limestone* which runs through western New York, and attains such magnificent proportions in Upper Canada, in the islands of Lake Huron, and on the west shore of Lake Michigan, has no existence in Pennsylvania. In Ohio the Niagara group consists of the Hillsboro' sandstone at the top, 30′; Guelph (Cedarsville) limestone, 150′ to 200′; Niagara (Springfield) limestone, 50′; Niagara shale, 5′ to 106′; and Dayton limestone at the bottom, thin and local; —total, 200′ to 300′.

If the Poxono shales and Poxono limestone of Pike and Monroe counties be the representatives of the Upper and Middle Salina on the Delaware river, the Niagara may exist there concealed; but if so, it cannot have the constitution of a massive limestone; and the case is complicated by the fact that Dr. Barrett at Port Jervis has found many Niagara forms in the limestone beds of the lower part of what is there considered No. VI (see G6, 145; and Nearpass's quarry section G6, 127–128, to be discussed under the head of Formation No. VI).

Professor White after studying Pike and Monroe (Report G6) and then the North Branch of the Susquehanna country (Report G7 pp. 110) thought it "very probable that the whole mass of red shale along the Delaware river, resting upon Medina sandstone, was not at all of Clinton age, but was a vast enlargement southeastward of the Bloomsburg Lower Salina, both the Niagara and the Clinton having thinned away in that direction." But this view it is impossible to accept if for no other reason than the persistency at all the Water Gaps of the Clinton Iron Sandstone, as already described.

The Clinton formation Va.

The Clinton Upper shales, limy beds and fossiliferous flaggy sandstones on both sides of Montour ridge, are 150′ thick, overlying (as shown in the section) the 3′ fossil ore bed. Similar strata of equal thickness underlie the ore. We have therefore about 300′ of Upper Clinton shales, in this district, over the Iron sandstone, 60′ thick; beneath which, in the Fishing creek gap, are seen 350′ of olive shales to water level. With this section of 713′ at Bloomsburg may now be compared a section in the Danville gap, where at least 500′ of the lower shales are exposed lying on No. IV making 953′; and the estimate of 500′ may perhaps be under the truth; but the entire thickness of Clinton cannot be far from a thousand feet.

Va. Section below Danville (*G7, f. 38*).

Salina, Bloomsburg red shale,	—	
Bluish-green shales,	20′	953′
Red shale,	4′	
Bluish-gray shales,	7′	
Limestone gray, very fossiliferous,	1′	
Bluish-gray limy beds,	25′	
Concealed,	5′	
Bluish, shaly limy beds, fossiliferous,	70′	
Limestone, hard blue,	5′	
Limy gray shales and thin limestones,	55′	
Limestone, very fossiliferous (FOSSIL ORE HORIZON),	1′	
Blue, shaly limestone, fossiliferous,	30′	
Bluish-gray limy beds sparingly fossiliferous,	100′	
Concealed, and olive shales,	100′	
Iron sandstone, visible,	30′	
Olive shales, fossiliferous near the middle; not well exposed, but estimated to be about,	500′	

With this may be compared a section of the beds at Danville made by Professor Rogers, in Geology of Pennsylvania, 1858, Vol. I, pp. 435–436. Reduced figures of both sections will be found in Plate CX, on page 738 above.

Va. Section near Danville (*Rogers*).

Surgent red shale, (*Bloomsburg*),	——	1039
Upper lime shales, sandy argillaceous green fissile slates, often highly fossiliferous, alternating with layers of fossiliferous limestone 1″–12″ thick,	160′	
Ore sandstone, a tough calcareous sandstone alternating with thin bands of shale,	8′	
Lower lime shales, green fissile slate with thin plates of limestone, and eight or nine thicker limestone bands, all fossiliferous,	40′	
Fossil ore,	1′ 4″	
The same as No. 4,	20′	
Upper green slate fissile, with thin plates of argillaceous sandstone,	50′	
Iron sandstone, with its *ferruginous* band,	59′ 4″	
Lower green slate, weathering yellow, generally sandy, often compact, not fissile, *its iron ore* lying about midway in the mass; *Buthotrephis gracilis* throughout,	700′	

The fossil ore will be described separately. It is only necessary to say here, that when mined below water level it is an ordinary, very fossiliferous limestone, holding only from 10 to 15 per cent. of iron. Above water level it has been decomposed and softened into a soft compound of one-third iron and one-third carbonate of lime.* It is never a single bed, but usually made up of two or more layers of iron-lime, separated by layers of slate of thin sandstone, and varying in the number and thickness of the several layers incessantly over every part of every district where it is mined. The iron-lime layers and the shale and sand layers which separate them, all alike yield numerous species of fossil shells:—*Avicula leptonata*, *Strophomena depressa*, *S. alternata*, *Atrypa reticularis*, *Rhynchonella robusta*, *R. neglecta*, *Beyrichia lata* and *Calymene clintoni*; but the list could undoubtedly be largely increased by a more systematic collection.

The Iron sandstone is a dark reddish brown, very compact, hard rock, resisting the weather and making a prominent little ridge on the surface of the ground, it is therefore the miners' guide from which he measures across to the outcrop of the fossil ore bed, a greater or less distance according to the gentleness or steepness of the dip. It does not seem to contain any valuable ore bed east of Fishing creek around Bloomsburg; but it has been extensively mined around Danville.

The Clinton olive slates and shales under the Iron sandstone have generally a dusky color, but weather greenish-yellow. Along Montour ridge they seem to grow more sandy and compact westward; at least they contain on the southern slope, a very hard olive-gray sandstone stratum,

* Two specimens of the *fossil ore* from the Bloomsburg Iron Co.'s mine on Fishing creek, analyzed by Mr. McCreath, gave the following results :

Bloomsburg fossil ore.	*No. 1. Hard ore.*	*No. 2. Soft ore.*
Metallic iron,	17.900	33.700
Sulphur,	.002	.009
Phosphorus,	.267	.407
Carbonate of lime,	64.053	41.160
Carbonate of magnesia,	5.516	4.116
Silicious matter,	1.520	2.950

which makes upon the surface a line of heaps of small angular fragments.

Great thickness of the Clinton in Pennsylvania.

Before leaving this district to go into the country west of the Susquehanna, it is well to notice the thickness of a thousand feet here given to the Clinton formation as a whole. In the State of New York the group of shales and limestones with fossil iron ore to which Professor Hall gave the name in Clinton county, New York, is only 80′ thick. Professor Claypole (F2 45) suggests a doubt of the possibility that these 80′ can represent the 989′ which he gives as his measurement of the Clinton in Perry county, that is, from the top of No. IV up to the Sand Vein ore bed, which lies a short distance beneath his Bloomsburg red shale. But we have seen a much greater thickness at the Water Gaps; and it is evident that the formation thickens gradually under southern New York and northern Pennsylvania; so that an increase from 80′ to 1000′ in the hundred miles is not only nothing extraordinary but even less than might be expected The Salina group along its New York outcrop varies from 300′ to 1000′ (Vanuxem reports it 700′ in middle New York); and it increases into Pennsylvania to nearly 1200′ in Montour's Ridge as we have seen; and to 1600′ in Perry county. An increase of the Salina from 300′ to 1600′ makes it easy to believe in an increase of the Clinton from 80′ to 1000′ in the same direction, that is, southward. Thus we get an increase of No. V from less than 400′ where it is thinnest in New York to 2600′ and more in Pennsylvania.

The Fossil Ore Beds of Montour's ridge.

The fossil iron ore industry of Pennsylvania has centred at Danville and Bloomsburg on the N. Branch Susquehanna, at Frankstown and Holidaysburg on the upper Juniata, at Orbisonia in southern Huntingdon, and along the Lewistown valley in Mifflin and Snyder counties,*

*The Danville beds were first worked in 1839 by D. L. Leavitt; in 1843 by Chambers, Biddle & Co. who built the first furnace; in 1851 by the Grove

The furnaces depend on a mixture of the limestone fossil (hard and soft) with the sandstone block ore. The limestone bed is usually triple under a slate roof; *upper split* of ore 5″ to 6″; sandslate parting, 6″ to 8″; *middle split*, "buncombe," or main bed, 15″ to 20″; sandslate parting 10″ to 12″; *lower split*, 0″ to 5″; bottom slate.

The percolation of rain water converts the hard fossil limestone into soft rich iron ore, for an uncertain and irregular depth beneath the surface; the limit of change being sometimes suddenly, sometimes gradually reached. The roof of the hard ore is solid, that of the soft ore cracked and crumbly. The bed worked on the south slope of Montour's ridge east of Mahoning creek for two miles pinches out and is unworkable for five or six miles further east; then comes in and is workable to Bloomsburg. On the opposite or north slope of the ridge the bed is regular east of Mahanoy creek, but turns to slate west of the creek. The Narrows 2 m. W. of Danville seems to be the limit of workable ore on the south slope.

The Block ore is merely a sandstone, very rich in iron near the outcrop, 18″ to 24″ thick, regular and continuous on to the slopes of Montour ridge; with regular sandstone roof and floor. A sandstone ore bed intermediate between the block and fossil beds, west of the creek, has not been mined.

The Birdseye fossil of Snyder Co. Below the block, and 150′ above the Medina, has been found at Choulaski, 3 m. W. of Danville, 5″ thick, and mined a little.

Two analyses of the *soft fossil ore* made at the Furnace laboratory in 1882 and (1889) read as follows: Water, 3.50 (7.05); Silica, 19.28 (24.11); Peroxide of iron, 67.30 (60.49);

Brothers (Montour Iron Co); in 1858 by Waterman & Beaver; in 1878 by Waterman alone; and now since 1880 by the Reading RR. Co. The period of highest activity was between 1858 to 1878. Prof. H. D. Rogers' elaborate report, pubished in his Geol. Pa. 1858, may be found reprinted as an appendix to White's Report of Progress G7, 1883. Valuable "notes on the iron ores of Danville, with a description of the longwall method of mining them," by H. H. Stoek of S. Bethlehem, published in the Transactions of the Am. Inst. Mining Engineers, Oct., 1891, bring our knowledge up to the present date.

Alumina, 7.94 (2.45); Lime, 0.86 (1.12); Magnesia, 0.80 (0.43); Sulphur, 0.02 (0.02); Phosphorus, 0.47 (0.70); Manganese oxide, (3.20.)

Two analyses of the *hard fossil ore*, one from the Purcell slope in 1888, the other from Welsh hill in 1889: Water, (0.18); Silica, 5.56 (6.04); Peroxide of iron 38.81 (28.65); Alumina, 4.34 (6.95); Lime, 25.17 (29.44); Magnesia, 2.85 (2.17), Sulphur, 0.10 (0.60); Phosphorus, 0.23 (0.15); Mang. ox. — (—); Carbonic acid, 23.00 (24.66).

An analysis of the *Block ore* by Booth & Garrett in 1882 shows its value at the outcrop: Silica, 27.28; Peroxide of iron, 52.23; Alumina, 8.29; Lime, 2.43; Magnesia, 1.54; Sulphur, 0.17; Phosphorus, 1.56; Manganese, a trace.

"The iron made from the ores in the western part of the Danville workings was cold-short. As the workings advanced towards the east it became neutral, and then red-short." (H. H. Stoek.)*

Before the Erie Canal and the Pennsylvania and other grand trunk railways changed the face of commerce of the United States, before the multiplication of high hot blast stacks fed with coke and anthracite, and before the Bessemer process brought the price of steel iron down to $40 a ton, the long rich fossil ore outcrops of Middle Pennsylvania were a source of wealth both to individuals and to the State. Now, still richer and more cheaply mined ores from the Lakes, from Cuba, Spain and Africa, have almost killed the fossil ore industry, and the hard fossil of the deeper parts of the beds is of little or no value.

*An interesting map of the gorge of Mahoning creek through Montours ridge at Danville and of the workings east of the creek, with the line of the axis of the anticlinal of the ridge, is given on page 7 of Mr. Stoek's memoir. The map is dated June, 1890. Slope A, sunk in 1853, has reached a depth of 500′, probably the greatest depth on fossil ore yet reached in this country. Six levels were worked, and the slope abandoned many years ago. The water level and Welsh hill gangways were worked 2500 yards, and stopped 1880, most of the ore exhausted. Five gangways in the Block ore, the longest 500 yards, have nearly exhausted it.

The Pursel slope, ¾ m. E. of the Frosty Valley slope, was sunk 600′ on a dip of 25° to 35°, with six lifts, and abandoned in 1889. The Grove slope was abandoned in 1882. Other mines have their separate histories. In September, 1889, all mining stopped, and since then the furnaces have been run mainly on Lake Superior ores.

CHAPTER LVII.

No. V on the Lower Juniata river.

In Perry county the outcrops of No. V are very numerous, arranged in zigzags, and continuous with each other around the points, furnishing to the farmer long stretches of fertile soil, and to the geologist a multitude of exposures, chiefly along brooks and small streams in the western half of the county. The upper part of Sherman's creek meanders through the formation where it is best exposed, and the Juniata river cuts square across it on the Juniata county line at Millerstown. Here on the south flank of the extreme end of Tuscarora mountain, we get the south dipping formation about $\frac{3}{4}$ of a mile wide; but the soft beds weathering easily afford no very good sections; the place of the upper Fossil ore and of the lower Iron sandstone being however plainly indicated by ridges on the surface. Several beds of ore occur in different parts of the Clinton.

The whole formation No. V is divided by Prof. Claypole into three Salina and seven Clinton groups, as follows:

Salina, Vc	Gray lime shale, ...	1600'±
	Variegated shale, (with Landisburg SS.), . .	
	(Bloomsburg) red shale, (with Bridgeport SS.)	

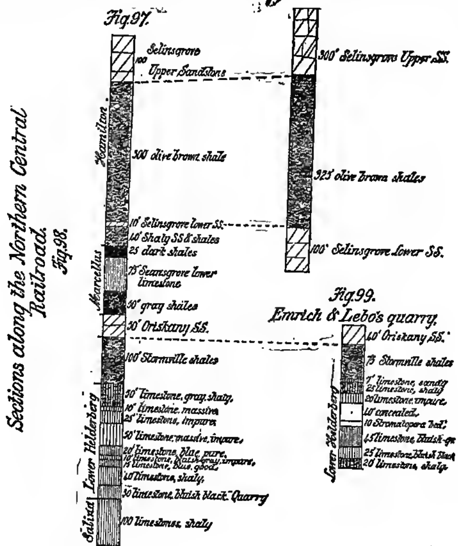
Niagara, Vb, apparently wanting.

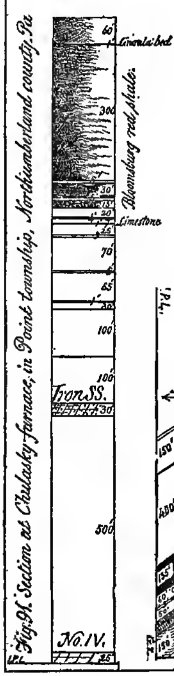
Clinton, Va	Upper lime shale, ...	1000'±
	Ore sandstone with fossil ore, ...	
	Lower lime shale, ...	
	Fossil ore (Danville beds), ...	
	Upper gray shale, ...	
	Iron sandstone with block ore, ...	
	Lower olive shale, ...	

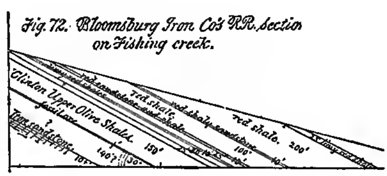
Before giving local sections, differing very much in different parts of the county, but showing the special arrange

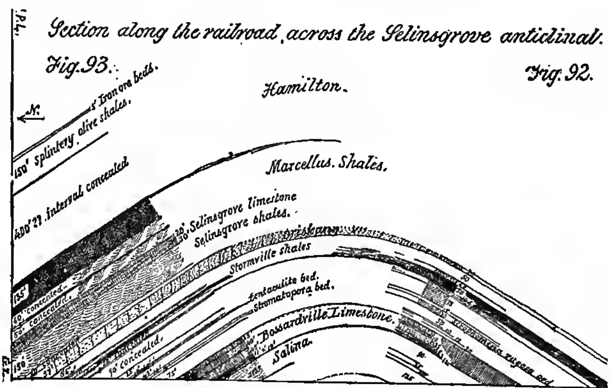
CXXII.

No. Vc, Salina, Bloomsburg red shale. I. C. White.









ment and character of the different beds in each group better than words can express, I will describe the groups, beginning at the bottom and proceeding upward in the historical order of their deposit to the top of the Upper Salina.

V a. The Clinton Lower olive shales are everywhere in the western and northern parts of Perry county, and the same is true of Juniata county, of great thickness; the upper part being often exposed, but the lower beds seldom seen, and their contact with the Medina white sandstone on which they lie is always concealed. The mass as a whole is soft, and of an olive green color, but contains numerous isolated thin beds of red sandstone resembling the Iron sandstone (overlying the mass) of which they are the geological precursors; being however, scantily fossiliferous, although a fair collection of species will doubtless in time and with some difficulty be procured. These red sandstone layers are imperfectly exposed chiefly in roadside cuttings in the western part of the county. The crest of the North or Blue mountain for nearly 20 miles west of the Susquehanna gap is made by these Clinton Lower olive shales; the outcrops of the Oneida and Medina running along beneath the crest upon the southern slope. The north edge of the crest is a steep rocky short slope of the hard dark purple Iron Sandstone, which is here extremely thick, measuring 80′ where it descends to the river in the gap. Its thin flat indestructible fragments have slid down the long north slope of the mountain, spoiling what would otherwise have been good arable land; and they have been carried down by the brooks and heaped along the banks at the foot of the mountain, deceiving people into the belief of a wealth of iron ore somewhere to be found in it, which belief of course has no foundation (F. 2, 335).

This *Iron sandstone* with its *Block iron* ore is a remarkable member of this series not only on the Lower Juniata but in other districts of middle Pennsylvania. It varies greatly in thickness, being 80′ at the Susquehanna gap and along the crest of the Blue mountain, 60′ at Danville, 25′ at Mifflintown, 7′ at Lewistown, 3′ at Mt. Union. On the

Potomac river it varies from 30′ at Wills creek to 3′ at the Capon axis. At Cumberland in Maryland it cannot be found; nor does it exist along Black Log mountain at Orbisonia.* In Perry county it is a very hard red sandstone, following the Clinton outcrops everywhere; but never a massive rock; seldom more than 10′ or 20′ thick; and composed of slabs each 2″ or 3″ thick. Its power of resisting the weather is remarkable; years of exposure seem to have no other effect than that of rounding off the corners and removing whatever soft or soluble matter it contains. Hence, although so thin a formation, its slabs cover large areas on the hillsides and seriously interfere with the tillage of what is otherwise good soil. From 5′ or 10′ in the northeast part of the county it increases southwestward to 20′ and more in the mountain near Landisburg. The base of the Iron sandstone on the Juniata is hard block iron ore, about 21″ thick, of good quality, but nowhere worked except near Millerstown. The ore does not appear at any of the well exposed outcrops of the Iron sandstone in the western townships of Perry county; it is evidently a local feature of the deposit.

The earliest traces of fish anywhere noticed in any country of the world have been found in this deposit.† Prof. Claypole found in the body of the Iron sandstone a thin layer closely packed with broken shields or *back plates* similar in character and condition to those in the Salina red shale (to be described directly);‡ and a few fine *fish spines*, like in the Landisburg (New Bloomfield) sandstone (to be described further on); and, quantities of small white phosphatic pellets, about as large as peas, undoubt-

*Professor Rogers recognizes it 4′ thick at the Lehigh Water Gap, and he gives to it the extraordinary thickness of 700′ at Muncy in Lycoming county.

†See the Buffalo Mills section. Since then however the discovery of fish plates and scales in the Grand Cañon of the Arkansas in Colorado beneath beds full of Trenton fossils, by Dr. Walcott, has carried the antiquity of marine vertebrates much further back.

‡The account of these fossils was not ready for Report F 2, and was published in the Q. S. G. Soc. London, No. 161, Feb. 2, 1885. p. 58.

edly *coprolites*, or the dung of the fish.‡ He named the fish *Palæaspis;* and the spine *Onchus clintoni.*

The Clinton Upper olive shale resembles the lower mass; is well exposed to the west where it contains more limestone. A good section was got in Little Illinois valley in Toboyne township (F2, 358.)

Little Illinois valley section.

Ore sandrock, hard, solid,	20′
Yellow sandstone and interbedded shales,	50
Yellow shale, Olive shale, Reddish shale, } fossiliferous,	150′
Iron sandstone with olive and yellow shale bands,	20′
Iron sandstone,	50′

The Upper olive shales cannot be distinguished in Perry county from the next group above it (Lower lime shales) with any satisfaction, as in other parts of middle Pennsylvania. They are separated from each other by the Danville fossil ore group; but this does not always exist; and where it is absent the whole mass between the Iron sandstone below and the Ore sandrock above may be called, as Professor Claypole habitually calls it in Report F2, Clinton Upper olive shales. In the section last given the Danville ore appears to be absent. The following section at Roundsley's near Millerstown, Tuscarora township (F2, 362) is in strong contrast with the last section, and well illustrates the incessant variation of all parts of Formation No. V as it is followed from place to place.

Millerstown section of Clinton rocks.

Ore sandstone,	Sand Vein ore bed,	1′	11½′
	Sandrock,	5′	
	Hematite ore,	½′	
	Sandrock,	5′	
	Olive shale,		160′
Danville ore,	*Iron sandstone,*	2′	3′
	Fossil ore,	1′	
	Clinton Upper olive shale,		300′
Iron sandstone,	*Sandstone,*	10′	11½′
	Block ore,	1½′	
	Clinton Lower olive shale,		—

‡Mr. McCreath found by analysis Phos. lime 32.39=Phos. acid 14.857=Phosphorus 6.478.

If these two sections be properly correlated, the 150′ of shales *without iron ore* in the one correspond to 460′ *with iron ore* in the other; which might raise a doubt that perhaps the Little Illinois valley Ore sandrock represents a very changed condition of the Danville ore group; but even then 150′ of shale at the one place would represent 300′ at the other.

The Danville Ore group is an iron sandstone with a bottom layer of fossil ore; just as the lower Iron Sandstone has at its base the block iron ore. The group is badly represented in this part of the state and is only mined around Millerstown.*

Of the *Clinton Lower lime shales* nothing can here be said further than that they are intimately connected with, if not a part of the group below them.

The Ore sandrock is in this district and generally in middle Pennsylvania a remarkably persistent and therefore an important deposit, varying in thickness from 10′ to 20′; some of its layers very hard and flinty.

The Sand-Vein fossil ore bed on its upper layers rests soft, friable and very fossiliferous. In Roundsley's section above given, a thin plate of red hematite ore, quite worthless, separates 5′ of upper sandrock from 5′ of lower. In the Little Illinois section we have 20′ of solid sandrock without any ore either in it or above it. The rock crops out as a low ridge along the surface of the country, infalliibly guiding the miner to the ore bed which lies upon it. This is the only ore mined to any extent in the neighborhood of Millerstown; varying from 12″ to 18″ in thickness; at some places hard and too expensive to mine; in others soft and rich. (For analysis see F2, p. 50.) In some places the ore is very fossiliferous. The exhibition of the sandrock and ore rising and falling over the numerous low rolls and

*It will be seen in discussing the three long sections of the middle Juniata district that there is really no fixed horizon for an *Iron sandstone*. This must be kept in mind by field workers when studying the outcrops of No. V.

arches in the Chestnut hills and parallel ranges is one of the interesting features of Clinton geology; and fine displays of such undulations may be seen in the "rainbow rocks" near Beavertown on the banks of Upper Sherman's creek in Jackson township; near Andersonburg in Madison township; near Bistline's mill on the township line, and at many other places.

The Clinton Upper Lime shales, olive green in color, and interbedded with numerous hard thin limestone layers, in which fossils are scarce, make the uppermost division of the Clinton formation immediately under the Salina (Bloomsburg) red shale. The greatest thickness of this group noticed in Perry county (125′) is in the following section at Waggoner's mill, Madison township, (F2, 256):

Waggoner's Mill section.

Salina Lower red shale, well exposed for more than		470′
Green shale in four thin beds, ...	3′	125′
Green sandstone, hard, ...	2′	
Lime shales, sandstone, and other concealed rocks, with an abundance of *Beyrichia notata*, and a varying dip, ...	120′	
Ore sandrock, ...		20′

This shale group varies very much; for in the foregoing section the great red shale lies directly upon the Sand-Vein ore bed.

The fossils of the different *Clinton groups* described above will be given after describing the *Salina groups;* but some general statements may be made here:—1. that very few fossils have yet been found in the Clinton Lower olive shale, chiefly from the scarcity of good exposures;—2. that the Iron Sandstone furnishes fossils in few places, but those which have been found are of considerable interest, being all of *Clinton* species;—3. that the Clinton Upper olive shale and Lower Lime shales in some places abound in well characterized Clinton fossils, *Beyrichia lata*, *Calymene clintoni*, and *Calymene blumenbachi*, *&c.;*—4. that these three species especially occur abundantly in the Ore sandrock;—

5. that the first two are found in the overlying Sand-Vein ore bed, associated with *Ormoceras vertebratum*;—6. that the Clinton fauna pure and simple, according to the character given to it by the New York geologists, that is, unmixed with their so-called Salina and Lower Helderberg species, stops at the Ore Sandrock. In report F2 therefore, Professor Claypole made this the top limit of the Clinton formation; and calls the Upper Lime shales over the ore bed "passage beds" because the Clinton species *Lingula oblonga* is mixed with the Lower Helderberg species *Beyrichia notata* (together with some undetermined *Lamellibranchs*). Above these shales no purely Clinton species have been found. But on the other hand, he found in the Salina Lower red shale (which is almost barren of animal life) at one or two places two New York *Lower Helderberg forms*, *Beyrichia notata* and *Leperditia alta*.

The Niagara formation of New York has not been recognized in the lower Juniata region; nor have Niagara fossils been seen there. The Niagara group, 240′ thick at Niagara Falls, dwindles eastward to 130′ at Rochester, and to nothing at Albany. It is therefore not surprising to miss it in middle Pennsylvania.

The Salina Lower (*Bloomsburg red*) *shales* in Perry county pass upward into the *Salina Middle* (*variegated* alternate red and olive) *shales* without any marked break; the red shales being 600′ or 800′ feet thick; and the Variegated shales having about an equal thickness. Their characters correspond with those given them by Vanuxem in his report on middle New York. He says, "The great mass of red shale is of a blood-red color, fine-grained, earthy in fracture, breaking or crumbling into irregular fragments." The Variegated shale he says "consists of shales and calcareous slate of a light green and drab color, intermixing and alternating with red shale at its lower part." Thus at the top of the series green, then red under it, green, red, bluish green and yellow (this latter by exposure to the air), then green and red layers, with a little white and greenish sandstone, being several repetitions of the first two; and finally red shale as the lowest visible mass. No better description can be given to these two groups in Perry county. As in New York so in several localities in Perry county, the red shale shows numerous green spots varying from an inch or two to several inches in diameter. Although in New York the red shale mass varies in thickness from 100′ to 500′ yet nowhere has a fossil been discovered in it, or a pebble, or anything extraneous, excepting a few thin layers of sandstone (Vanuxem report 3d district, p. 97).

The scarcity of fossils in these red shales is very remarkable, although they are not wholly absent, *Beyrichia notata* and *Leperditia alta* being mentioned in the last paragraph.

These red and variegated marls, occupy a large area along the Juniata-Perry line and in the western and southern valleys; the Red shale outcrop lying at the foot of the numerous mountains, and the Variegated shale outcrop fringing it on the valley side, and running out into long narrow pointed tongues of soil eastward, as shown on the geological map of the county. For instance, the whole of the long strip running from Loysville, Tyrone township, eastward for 12 miles past New Bloomfield consists of the Variegated shales. Both formations make a warm fertile soil, and render the valley part of western Perry through which Sherman's creek meanders its best farming district.

The Bridgeport sandstone in the *Salina Lower* (*Bloomsburg red*) *shale*, is a most remarkable deposit when all the circumstances are considered. This very singular bed of hard flinty sandstone is best seen on Sherman's creek in Spring township south of Bridgeport, brought up in a low arch by the Welsh mountain anticlinal. Dipping gently both ways from the middle line of the arch and disappearing under water in a few yards, it is about 8′ thick, very hard and solid in the middle, but more soft and shaly toward the top and bottom. How far it extends eastward cannot be known. As it passes under Quaker hill in Tyrone township, bordering Spring township on the west, it is somewhat thicker but nowhere coarser than in the arch on the creek. It is used as a rough building stone; but like the Oriskany sandstone outcropping near by in the neighborhood it cannot be dressed with success, as it breaks irregularly (F2, 336). A smaller bed, perhaps the same, is seen in the red shale near Bistline's mill on Sherman's creek in Madison township, only 2′ thick (F2, 57). Here its place in the red shale is well defined by the following section (F2, 255):

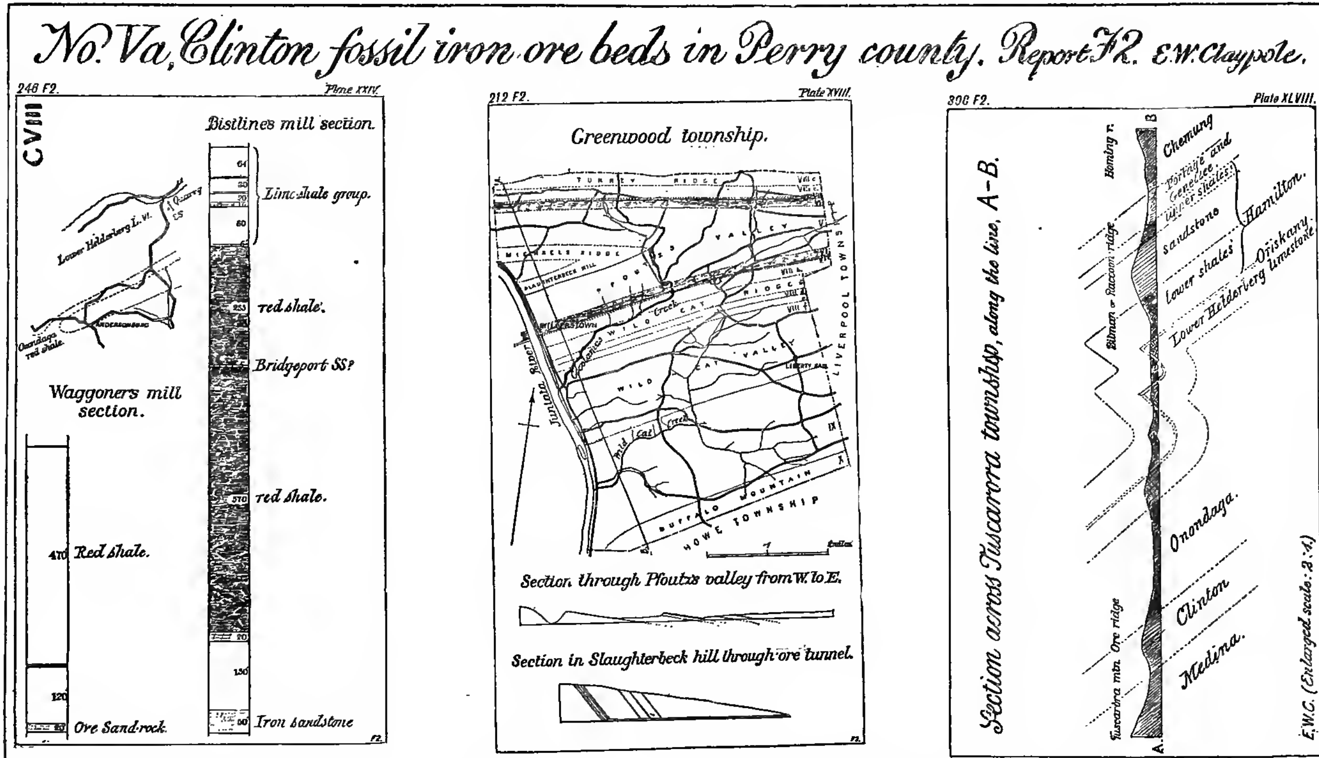
Bistline's Mill section.

Salina,		Gray shale,	64′	212′
		Limestone, thin,	—	
		Gray shale,	30′	
		Limestone, shaly,	2′	
		Shale,	20′	
		Limestone, quarried,	10′	
		Shale,	80′	
		Lime, shale, Limestone.	6′	
	Bloomsburg,	Red Shale,	255′	830′
		Bridgeport sandstone,	5′	
		Red shale,	570′	
Clinton,		*Iron sandstone,*		50′
		Upper olive shale, possibly,		150′
		Ore sandrock,		20′

But no sign of any such bed has been seen at other exposures of the red shale along the creek between Centre and Bridgeport; although at Waggoner's mill an almost complete section of the red shale mass is visible; see top of section given above.

That the *Bridgeport sandstone* is an extensive deposit, is shown by the fact, that it crops out on the sides and tops of the ridges in Kennedy's valley and Green valley in Tyrone township, making rough ruggid terraces, and its flinty fragments making the clearing of fields laborious. Near Egolf's saw mill is one of the best exposures of it, its ragged edge 12′ thick standing out with a dip of 45° N. N. W. from the north bank of McCabe's run (F2, 373).

The theoretical importance attaching to such a deposit is very great, and has a wide bearing upon the general geology of middle Pennsylvania; illustrating as it does the impossibility of obtaining any knowledge of the origin of many


No. Va, Clinton fossil iron ore beds in Perry county. Report F2. E.W. Claypole.
248 F2.
Plate XXIV.
CVIII
Lower Helderberg L. VI.
Quarry
Onondaga red shale.
Andersonburg
Waggoners mill section.
470 Red shale.
120
Ore Sand-rock.
Bistlines mill section.
64
30
20
60
Lime-shale group.
253 red shale.
Bridgeport SS?
570 red shale.
20
150
90 Iron sandstone
212 F2.
Plate XVIII.
Greenwood township.
Turkey Ridge
Pfoutzs Valley
Michaels Ridge
Slaughterbeck Hill
Wild Cat Ridge
Wild Cat Valley
Wild Cat Creek
Juniata River
Millerstown
Liberty Hall
Liverpool Township
Buffalo Mountain
Howe Township
Section through Pfoutzs valley from W. to E.
Section in Slaughterbeck hill through ore tunnel.
306 F2.
Plate XLVIII.
Section across Tuscarora township, along the line, A-B.
Tuscarora mtn.
Ore ridge
Bilman or Raccoon ridge
Homing r.
A.
B
Chemung
Portage and Genesee upper shales
sandstone
Hamilton.
lower shales
Oriskany
Lower Helderberg limestone
Onondaga.
Clinton
Medina.
E.W.C. (Enlarged scale: 2:1.)

of our thin deposits, beyond a suggestion that they are the northern knife-edges of thick and important sand formations which once spread southward for an unknown distance over the region now occupied by the Great Valley and the South Mountains. For this Bridgeport sandstone evidently increases in thickness southward toward the Great Valley, from which it has of course been long since swept away. And the reports of Mr. Dewees on Juniata and Perry counties (still unpublished) describes similar sandrocks in other formations increasing southward in the same manner, as if generated in mass in an area from which they have been entirely swept away.

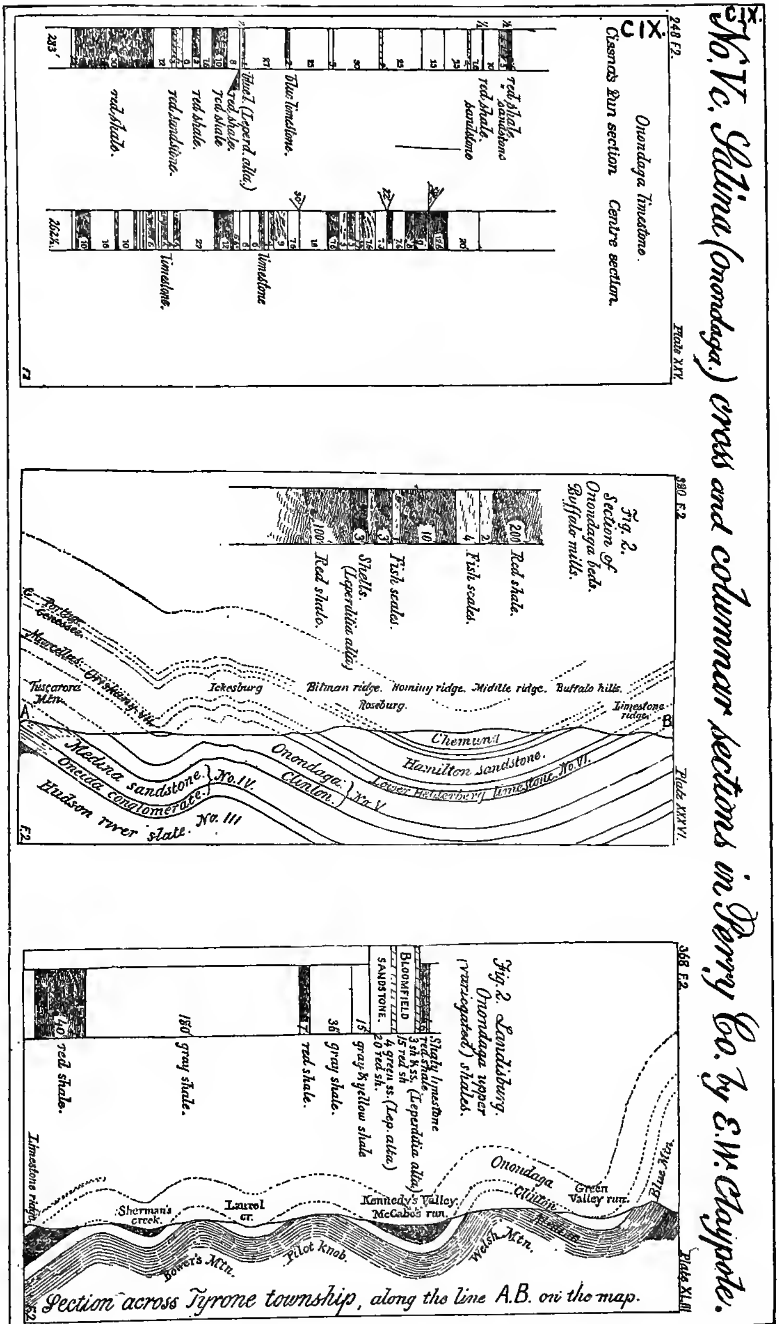
The fish which inhabited the Clinton waters continued to live in the succeeding Salina age, and traces of their existence are found in a few places where the red shales are exposed. One of these places is at, and another half a mile east of Buffalo mill, Raccoon valley, Saville township, Perry county, where are two good exposures of the following section.*

Buffalo Mill fish beds.

Salina red shales,		200′
Grayish yellow shales,	2′	24′
Red shale and sandstone with fish scales (?),	4′	
Red shale and sandstone,	10′	
Red shale and sandstone with fish scales(?),	1′	
Red shale, sandy,	3′	
Grayish-yellow shale,	1′	
Red shale (almost a soft fossil ore), with *Leperditia alta,*	3′	
Salina red shales,		100′

The Salina Variegated shale has been sufficiently described above, in connection with the Salina Lower red shale; but the detail structure of the group will be seen from the following section, made along the valley from Bloomfield to Enslow's mill.

*F2, p. 324, Fig. on p. 320. See also Prof. Claypole's paper before the London Geo. Soc. Dec. 17, 1884 (Q. J. No. 161. p. 58.) "Comminuted scales" are associated with an abundance of *L. alta* in the other beds. The scales are hin and fragmentary, and seem to be composed of homogeneous material, destitute of bone cells and canicules, but resembling in all respects the *solid layer of Palæaspis.* He was sometimes inclined to consider them coprolitic. The *Palæaspis* will be described on a following page 770. See also what is said of fish scales under Iron Sandstone, page 756 above.


CIX.
No. Vc. Salina (Onondaga.) cross and columnar sections in Perry Co. by E. W. Claypole.
248 F2.
Plate XXV.
CIX.
Onondaga limestone.
Cissna's Run section
Centre section.
red shale.
" sandstone
red shale.
sandstone
blue limestone.
blue l. (Leperd. alta.)
red shale.
red shale
red shale.
red sandstone.
red shale.
283′
262½.
limestone
limestone.
F2
320 F.2
Plate XXXVI.
Fig. 2.
Section of
Onondaga beds.
Buffalo mills.
Red shale.
Fish scales.
Fish scales.
Shells.
(Leperditia alta)
Red shale.
Bitman ridge.
Hominy ridge.
Middle ridge.
Buffalo hills.
Limestone ridge.
Roseburg.
Ickesburg
Tuscarora Mtn.
Chemung
Hamilton sandstone.
Lower Helderberg limestone. No. VI.
Onondaga.
Clinton.
No. V.
Medina sandstone.
Oneida conglomerate.
No. IV.
Hudson river slate. No. III
A
B
F.2.
368 F.2.
Plate XLIII
Fig. 2. Landisburg.
Onondaga upper
(variegated) shales.
Shaly limestone
red shale.
3 sh & ss. (Leperditia alta).
15 red sh
4 green ss. (Lep. alta)
20 red sh.
BLOOMFIELD
SANDSTONE.
15 gray & yellow shale
36 gray shale.
7 red shale.
180 gray shale.
40 red shale.
Blue Mtn.
Green Valley run.
Onondaga
Clinton
Kennedy's Valley.
McCabe's run.
Welsh Mtn.
Pilot knob.
Laurel cr.
Sherman's creek.
Bower's Mtn.
Limestone ridge.
Section across Tyrone township, along the line A.B. on the map.
F2

Enslow's Mill section.

Salina Middle (Variegated) shale (F2, 233).

Gray lime shales with wrinkled or cracked surfaces.		
Green shale,	2′	
Red shale,	4′	
Brown sandstone and shale,	1′	
Partly concealed (with Landisburg SS.),	120′	
Limestone and lime shale soil,	116′	
Red shale,	thin	
Gray shale and limestone,	40′	
Red shale,	4′	
Gray shale,	144′	
Limestone,	thin	
Gray shale,	32′	801
Red shale,	thin	
Gray shale,	48′	
Red shale,	thin	
Gray shales with limestone beds (springs of water),	30′	
Red shale,	4′	
Gray shale,	2′	
Red shale,	6′	
Gray shale,	72′	
Gray and red shale mostly,	48′	
Yellow shale,	3′	
Yellow and gray shale,	125′	

Two other sections in Madison township may be compared with the above:—

1. The Cissna's (Cedar) run section (F2, 256), made along the road running south from the turnpike through the valley; the upper part of which shows the passage of the Salina Middle into Salina upper.

2. The Centre village section (F2, 258), made along the turnpike west of the village; in apparently the same beds as are displayed in the railroad cutting at Patterson (Mifflintown).

In the first section, the appearance of *Leperditia alta* so low down is noteworthy. In the second section, the bed marked *b*, is a mass of the shells of *Leperditia alta*, resembling the layer at Patterson in Juniata county. The bed *c*, is really a part of *b*, but harder, more brittle, and breaking with a square fracture, and also composed of the shells of a *Leperditia*, apparently of the same species.

The bed marked *d*, is a hard, dark close limestone, yielding very little except *Leperditia* shells badily preserved and probably of the same species.

Cissna's Run Salina Middle section.

Top of section. Green shale in main road.

Red shale,	2′ 6′
Bright green sandstone,	6′′
Red sandstone,	5′ 0′′
Green and yellow sandy shale,	10′ 0′
Red shale,	6′′
Green shale,	7′ 6′′
Hard red sandstone,	2′ 0′′
Dark shale,	15′ 0′′
Yellow shale,	15′ 0′′
Solid dark shale,	25′ 0′′
Sandstone,	2′ 0′′
Dark shale weathering yellow,	30′ 0′′
Green shale,	3′ 0′′
Dark shale, Yellow shale, Green shale,	25′ 0′′
Solid blue limestone,	2′ 0′′
Yellow shale,	27′ 0′,
Solid blue limestone, *Leperditia alta*,	1′ 0′′
Green shale,	2′ 0′
Space covered 20 feet.	20′ 0′′
Red shale,	20′ 0′
Green shale,	8′ 0′′
Red shale,	10′ 0′′
Green shale,	7′ 6′′
Red shale,	5′ 0′′
Yellow shale,	6′ 0′′
Shaly green sandstone,	4′ 0′′
Red sandstone,	3′ 0′′
Green shale,	12′ 0′′
Red shale,	50′ 0′′
Green shale,	2′ 6′′=303′

Base of section. Ground not exposed.

Centre Village Salina Middle section.

Green shale,	20′ 0′′
Red shale,	12′ 6′′
Green shale,	9′ 0′
Red shale,	6′ 0′′
Green shale,	7′ 6′′
Red shale,	3′ 6′′
Space covered 22 feet,	22′ 0′′
Green shale,	7′ 6′

	Green shale mottled with red,	7 6″
	Red shale,	3′ 6′
	Green shale,	2′ 6
	Red shale,	5′ 0″
d.	Green shale with thin bed of LIMESTONE, *L. alta*,	5′ 0′
	Red shale,	7′ 6″
	Green and yellow shale,	18′ 0″
	Space covered 30 feet,	30′ 0′
	Green shale,	7′ 6′
	Green shale mottled with red,	9′ 0′
	Red shale,	3′ 0
	Green shale,	3 0
c.	Sandy LIMESTONE, coarse, } *Leperditia alta*,	2′ 0
b.	" " fine. }	1 6
	Yellow shale,	6′ 0
	Dark shale,	6 0′
	Green shale,	4 6
	Red shale,	12 0
	Green shale,	22· 0·
	Red shale,	4 0
	Green shale,	4′ 0′
a.	Dark flaggy LIMESTONE, *Leperditia alta*,	4 0
	Yellow shale,	2′ 0′
	Green shale,	2′ 0
	Red sandy shale,	6′ 0
	Light green shale,	2′ 0·
	Yellow shale,	2′ 0″
	Green shale,	2′ 0′
	Red shale,	2′ 0″
	Yellow shale,	10′ 0
	Red shale,	2 0″
	Green and yellow shale,	10′ 0·′
	Red shale,	10 0″
	Green shale,	2′ 0″=315′

Base of section just before reaching turn of road.

*The Landisburg fish-bed sandstone** plays the same rôle in the Salina Middle group which the previously described Bridgeport sandstone plays in the Salina Lower group, as seen in the following section.

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* In Report F 2, this is called the Bloomfield sandstone, because running under the county seat of Perry, New Bloomfield; but I have changed the name to Landisburg, where it is equally remarkable, so as to avoid confusion between the names Bloomfield and Bloomsburg.

Landisburg section (*F 2 372*).

	Salina, uppermost gray shales,		about 200′
	Limestone, shaly, belonging to Salina Upper group,		—
	Red shale,		1′
	Limestone, shale, with wrinkled surfaces,		6′
Landisburg SS.	Hard olive shale and sandstone with *Leperditia alta*,	3′	42′
	Red shale and sandstone,	15′	
	Gray sandstone with *L. alta*,	4′	
	Red shale and sandstone,	20′	
	Gray and yellow shale,		15′
	Gray shale,		36′
	Red shale,		7′
	Gray shale,		180′
	Red shale,		40′=327′

The *Landisburg sandstone proper* is a thin bed of soft friable sandrock, breaking up into brick-shaped fragments, and varying in color from dull reddish to olive greenish. Its outcrop, sometimes 10′ thick, makes a well marked low ridge easily traceable continuously across Centre township; passing under New Bloomfield ;* a good exposure of it being seen half a mile east of the town, on the Newport road, and others at various places along the valley road.

Leperditia alta shells occur in great abundance in this little group of beds, which however derive their chief importance to the geologist from their *fish remains*, which inspire the highest curiosity and excite unwonted interest because they antedate the oldest Silurian fish of any country as yet studied by geologists.†

The oldest fossil fish of England left their plates and

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* The harder layers crop out in the streets with an almost vertical dip. The low cutting through it, east of the town, displays its alternations of color and hardness very distinctly.—Professor Rogers describes it in his Geol. Penn. 1858, p. 329, as a bed of argillaceous sandstone in layers of various colors, dull red, gray, white and greenish ; breaking up into small rectangular fragments; with a total thickness of only 8′ or 10′, yet making a continuous ridge along the surface. He places it in the upper part of his Scalent Gray marl near the bottom of his Scalent Limestone. Professor Claypole says (F 2, 55) that no such bed exists near the top of the Salina Upper Gray shale; but that it lies near the top of the Salina Middle Variegated shales. He draws attention to another error in the Final Report of 1858; namely, Professor Rogers' estimate of 100′ for the thickness of the Variegated marls along the Tuscarora mountain ; whereas they are about 700′.

† Except Dr. Walcott's Grand Cañon fish in Colorado.

spines in the *Upper Ludlow* "*bone bed*," of the age of our Lewistown (Lower Helderberg) limestone formation No. VI. Their heads and necks were protected from unknown enemies by stony or enameled shields; and their backs were armed like the modern sharks with fluted spines. These bucklers and spines with some teeth are the only remains of them to be found in the rock; their soft backbones were not preserved; they are placed by zoologists in the families of sharks and sturgeons; and they lived in a crowd of starfishes, aboriginal lobster-like creatures (Eurypterus), coral animals, trilobites, and a vast variety of shell fish of both kinds (brachiopods and lamellibranchs.)* They are supposed to have been of at least eleven different genera (and nineteen species); some of them named from the shapes of their bucklers (*Auchenaspis*, *Cephalaspis*, *Eukeraspis*, *Pteraspis*, *Scaphaspis*, *Cyathaspis*); others after the shapes of their teeth (*Plectrodus*, *Scaphodus*, *Sphagodus*, *Thelodus*); two species are called simply *Onchus* (ονυξ, a birds' claw); and one *Thysetes* (fringed, or tasseled). Most, if not all them were of small size, their back plates only two or three inches long, and their spines little more than an inch long. The gigantic and terrible armoured fish of No. VIII had not then begun to appear. Some of these fish of No. VI continued to live into No. VIII; as *Auchenaspis*, *Cephalaspis*, *Cyathaspis*, *Eukeraspis*, *Pteraspis*, *Scaphaspis*, and were joined by at least 86 other species. But when did they make their first appearance? Their numbers and variety argue for their long previous existence; yet their remains seemed to be confined to the Upper Ludlow (No. VI) strata; until the discovery in 1859 that at least one species, *Scaphaspis ludensis* ("the boat-shaped shield of Ludlow") had existed in *Lower Ludlow* times, corresponding to the New York *Waterlime* and our *Cement bed* age, and perhaps also to the upper part of our Salina division of No. V.†

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*Geikie's Text-Book, 1882, p. 680, 681.—Phillips' manual, by Etheridge, 1885, p. 149.

†Murchison and Ramsay consider the Lower Ludlow as representing the Waterlime; and think that the overlying Lower Hilderberg proper is want-

The order of the formations in Great Britain is given in a foot note. No fish has been found in Europe beneath the Upper Ludlow, except a single specimen of *Scaphasis*

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ing in Europe, and ought to come in between the Lower and Upper Ludlow. James Hall agrees with them in this and also in making our Niagara the Wenlock limestone. Murchison gives the following species as common to the Niagara and Wenlock limestones :—*Calymene blumenbaehii* (or *niagarensis*); *Homalonotus delphinoeephalus*; *Bumastes barriensis* (*Illænus ioxus*); *Rhynchonella cuneata*; *Rhynchonella wilsoni*; *Pentamerus galeatus* (*a*); *Orthis clegantula*; *Orthis hybrida*; *Orthoceras annulatum*; *Euealyptoerinus decorus*; *Bellerophon dilatatus* (*b*): *Favosites gothlandiea*; *Favosites alveolaris*; and *Halysites catenulatus*, (*a*, *b*, are however not recognized as Niagara species by Claypole.)

Hall says (Pal. N. Y. vol. 2, p. 321) that the Niagara limestone and in fact the whole Niagara group of Western New York is represented in Eastern New York by the thin *Coralline Limestone* although it cannot be distinctly traced westward beyond Herkimer county. At Scoharie it rests on a green shale which represents the whole Clinton formation (V); and is capped by shaly drab limestones only 15′ to 20′ thick, which represent the great mass of the Pennsylvania Salina formation (V). Unfortunately the coralline and the shaly drab limestones with the overlying *Tentaculite* limestone (VI) were originally thrown into a triple-group and called the Water-Lime. The Niagara of the west can be followed eastward only as far as Oneida county where it gets very thin and concretionary, with few fossils; from Oneida to Herkimer exposures are bad, but no doubt the formation runs on and becomes the Coralline limestone at Scoharie.

Below the English Ludlow lies the Wenlock formation, corresponding to our Niagara and Clinton divisions of No. V; at its top the Wenlock limestone (100′ to 300′) with 76 species of corals (especially *Halysites catenulatus* by which we recognize Niagara strata); 67 species of crinoids; 34 species of worms; an abundance of trilobites, especially the *Calymene blumenbachii* ("the Dudley locust") which, however, prolonged its existence through all the formations between No. I to No. VII; 96 species of brachiopod shells, among which is the famous *Pentamerus galeatus*; 43 species of lamellibranch shells (*Pterinia*, *Cardiola*, *Cueulella*, *Grammysia*, *Modiolopsis*, *Ctenodonta*; an abundance of Orthocerata and other gasteropod shells; pteropods like *Conularia sowerbyi*: *Bellerophon wenlockensis* and other heteropods, and especially the oldest lobster-like (*Eurypterus*, *Hemiaspis*, *Pterygotus*) animals by which we know the *Water-lime* formation in New York.

In the English Wenlock limestone, therefore, we seem to see both our Niagara and Lower Helderberg Water-lime formations united, *without the intervening Salina* formation. This only shows how impossible it is to correlate the deposits on the two sides of the Atlantic by merely studying the fossilized remains of the animals which lived when they were made. The absence of our *Salina* in England makes the passage of V into VI uncertain there. The absence of our *Oriskany* in England makes the passage of Silurian (No. VI) into Devonian (No. VIII) there equally uncertain. We know nothing about the times and directions of the animal migrations which must have taken place; whether the Halycites, the Pterygotus, the *ludensis* in the Lower Ludlow shales, under the Aymestry limestone, and therefore somewhere near the top of our Salina.

The *Landisburg fish bed* in the *Middle Salina shales* should therefore be much older than the oldest known European specimen; the fish plate fragments of the *Bridgeport sandstone* in the *Lower Salina red shales* older still; and the fish plate fragments in the *Iron sandstone* of the *Clinton*, very much older still.

The fish remains here spoken of are also the oldest found in America except in Colorado. The *Macropetalichthys*, *Dinichthys*, *Onychodus*, *Coccosteus*, etc., of the Ohio survey, and the *Coccosteus*, *Cephalaspis* and *Ctenacanthus* of Canada, have all been found in the Corniferous limestone near the bottom of formation No. VIII. As this Devonian limestone was called the *Onondaga limestone*

Onchus, the Pterichthys lived first in the American and afterwards in English waters, or the reverse; therefore we cannot assert dogmatically that our Niagara limestone is the English Wenlock limestone; not to mention the fact so forcibly stated by Geikie (p. 676) that all the English Upper Silurian limestone formations are local deposits, thinning out to knife edges and letting the shales above and below them come together. It will be seen in the chapter on No. VI that the same thing happens with our limestone formations; but it happens with all sea deposits of every kind. If the Wenlock (Dudley) limestone of England disappears thus, so does the great Niagara limestone of the north disappear toward the Hudson and Susquehanna.

The underlying Wenlock shales of England, 1600′ thick to the north and only 640′ in the Malvern hills, carry many of the fossils which are abundant in the overlying limestone; but corals are rare; the Leptæna, Orthis, Strophomena, Atrypa and Rhynchonella shells generally small in size; the "straight horn" shells (*Orthoceras*) specially abundant; trilobites numerous; *Grapholithus flemingii* characteristic, with the No. III species *Monograptus priodon.*

The underlying local thin Woolhope nodular limestone shale holds 24 species of tribolites (*Bumastes*, *Homalonotus Phacops*, *etc.*) and 56 species of brachiopod shells (*Atrypa reticularis*, *etc.*); *Euomphalus sculptus* and *Orthoceras annulatum* are also common.

The lowest Wenlock division, the Tarannon shale, has an extreme thickness of 1500′, and its outcrop runs the whole length of western Wales, as the "paste rock" of Sedgwick; and yet it thins entirely out on the English border letting the Woolhope limestone down on to the Upper Llandovery (May hill) sandstone formation, our No. IV; which is precisely what happens to our Clinton, Niagara and Salina No. V in southern New York. Like our Clinton shales, the Tarannon shale of Wales is almost destitute of fossils.

and the Salina formation was also called the *Onondaga formation*, a confusion has resulted in labeling fossils ; Hugh Miller, for example, copies the figure of a *Machæracanthus major* spine from the Corniferous (Onondaga) limestone as if it came from the Salina (Onondaga) salt group.*

The Salina lower red shales were considered by the early surveys of Pennsylvania and Virginia as the upper division of the Clinton formation No. V ; and H. D. Rogers told Lyell on his visit to America in 1841, that he and his brother W. B. Rogers had traced the scales of *fishes* through strata of Clinton age from the southwest part of Virginia to the North Branch Susquehanna in Pennsylvania. At that date he had no doubt that these remains were of the nature of the fish scales which had already then been seen in formations VIII and IX.† But before his geology of Pennsylvania got published at Edinburgh in Scotland, in 1858, he had acceded to the general sentiment of the British geologists that no true fish remains could be found in any formation of older date than the early Devonian strata with their plated fish, corresponding to the then recently discovered Corniferous limestone fish of Ohio. "Hitherto (he writes) no traces have been discovered of any vertebrate animal‡ whatsoever during . . . the Cambrian and Silurian periods of the English geologists, or the equivalent *Primal*, *Auroral*, *Matinal*, *Levant* [IV], *Surgent* [Clinton V], and *Scalent* [Salina V], periods . . . of the Pennsylvania survey.§ Whatever the Clinton scales were, they could have not belonged he thought to vertebrate animals, i. e. to *true* fish. Even now a geologist may be pardoned for hesitating to give that title to creatures which had nothing sufficiently solid

*Footprints, p. 143, from Silliman's Journal [2] I. 62. Norwood and Owen in Sill. J. [2] I. 397, make the same mistake with a *macropetalichthys*.

†I myself picked up on the Cowanesque creek road in Tioga county, in the spring of 1841, the first Holoptychius plate. It was lost with a box of other fossils and minerals on the way to Philadelphia.

‡Murchison in his Siluria, 1859, p. 268, 269, was more cautious, asserting that "no *bony* vertebrated animals had been called into existence" in Silurian times.

§Geol. Pa. II, p. 824.

within them to be preserved in rocks, and which were not endowed with or had not yet acquired the faculty of secreting bony tissue even at their skin.*

Huxley† made but one family of the old buckler-headed fishes CEPHALASPIDS ("head shields"). Professor Lankester‡ divides them into two;—OSTEOSTRACI, those which secreted true bone (bonecells and little tubes, *lacunæ* and *canaliculi*);—and HETEROSTACI, those which were of inferior organization and secreted no true bony tissue. The later (Devonian) fish had real bony head-pieces and back-plates; but the earlier (Silurian) fish wore armour which does not know a true bone-structure. This has led to the suspicion that these earlier fish had no vertebral column, or back-bone, and therefore ought not to be called fishes;

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*The reader is reminded (p.——) that Pander's *Conodonts*, once supposed to be fish teeth, are now supposed and almost proved to be the dentition of aboriginal leeches; and Geikie considers it probable that the *Onchus spines* belonged not to fishes but to crustaceans. (Text book, p. 683.)—Hall's Niagara *Onchus dewi*, for example, Pal. N. Y. II, 1851, plate 71, Hall himself considered the true fish character of the spine first discovered by Col. Jewett in Niagara shale at Lockport to be ambiguous, because it resembled no known fish spine; but that the true fish characters of the second and more perfect spine 6 inches long, found by Col. Jewett was sufficiently proved by its broadened base, showing that it was moved by muscles, and being 1¼ inches in diameter just above the base, the fish to which it belonged must have been a large and powerful animal. One spine nearly as large as this was afterward found in the Delthyrus shaly limestone; but those found in the Salina, and those found in Corniferous, were all much smaller. Hall considers all the *Clinton* fossils found before 1844 to be defensive fin bones of fish; and he concludes by saying: "From the Clinton group upward we have these remains in every successive rock as far as the Red Sandstone of the Catskill mountains," formation No. IX (Pal. N. Y. Vol. 2, p. 319).

Agassiz regarded *Onchus murchisoni* and *Onchus tenuirostratus* of the Ludlow rock as true fish spines. Claypole's *Onchus pennsylvanicus and Onchus clintoni* do not resemble the spines of trilobites and other crusta, ceans, but the rounded fluted spines of fish. They are about ½ an inch long by ⅛ inch diameter at the base, slightly curved, originally hollow perhaps, or perhaps with an original core surrounded by a sheath, the outer surface of which is fluted (8 ridges in *O. pennsylvanicus*, and probably 24 in *O. Clintoni*), the ridges rounded, height half their breadth, bases touching each other. See Claypole's paper in Q. J. G. S. XLI, 61.

† Journal of the London Geological Society, Jan. 6, 1858, XIV (No. 55), p. 267. On Cephalaspis and Pteraspis; with two plates, showing the microscopic structure of the buckler.

‡ Memoirs of the Palæontological Society, 1867, 1869.

should be excluded from the order of vertebrate animals. They certainly seem to indicate a passage from invertebrate to vertebrate life; as if a lobster was making an effort to become a fish; or rather, as if the idea of a trilobite was being replaced by the idea of a *Pterygotus* in one direction, of a *Holoptychius* in another, as the inventor of animal forms proceeded with his work. No one can tell what the *Palæaspis*, *Scaphaspis*, *Cyathaspis* or *Pteraspis* looked like as they swam through the open Clinton sea, or fed among the corals of the Lower Helderberg age.

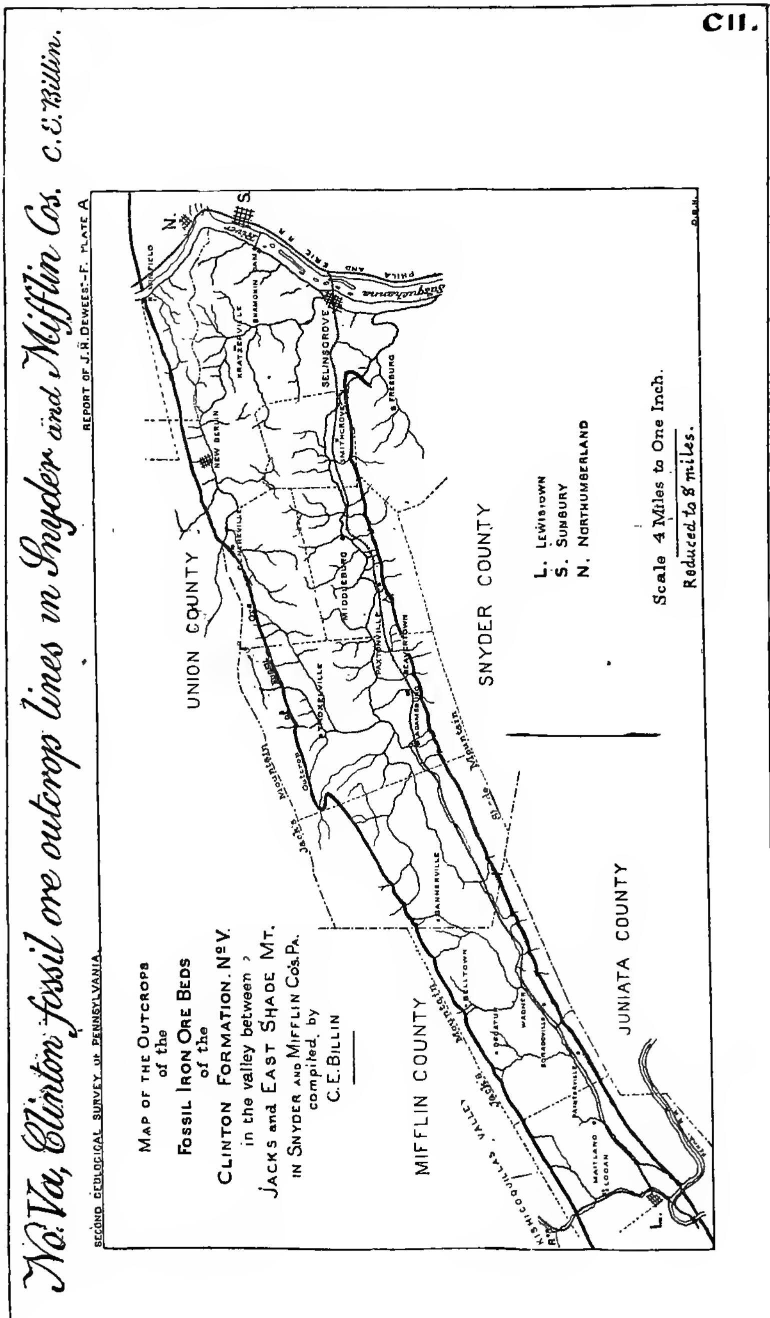
The microscopic structure of the shield of *Pteraspis* (*Scaphaspis*) *lloydii* given by Huxley, shows four layers, which together are only $\frac{1}{40}$ of an inch thick; the outer layer being a pavement of minute enamel cups, bottom up, growing on a layer of whitish substance traversed by little veins or canals; this is supported by a third layer of fibrous structure, which covers the fourth and innermost layer made up of exceedingly thin leaves (see last figure on Pl. LXIX). The structure of PALÆASPIS is analogous, but somewhat different. There are only three regular layers. In the outer layer the veins instead of running irregularly, have a striking parallelism; the tubules (minutor veins) branch upward and being now filled with opaque matter appear under the microscope like a beautiful little forest growth looking like *dendrites* on marble (Fig. 2). But the chief distinction is in an apparant absence of the inverted cups of enamel studding the exterior surface.

With regard to the plates themselves, each of these earlier fish seems to have had but *one* upon its head, which is the characteristic feature of Lankester's *Scaphapsis;* whereas his *Cyathaspis* in the higher strata of Great Britain had *four;* and the *Pteraspis*, *seven*, arranged in arrowhead shape. Claypole's plates are of two shapes, one oval with the front end very pointed and the hind end cut off nearly square; the other, more slenderly oval, with the front end cut off in a hollow curve and the hind end cut off nearly square, suggesting the possibility of other plates. The sculpturing of the surface in fine waving ridges is shown in Pl. LXIX. The plate has three layers, the inner one about $\frac{1}{240}$ inch thick lining the concave side of the plate solid, but indistinctly laminated, with minute circular holes ($\frac{1}{600}$ inch diameter) scattered through it; the second or middle layer ($\frac{1}{50}$ inch thick) is made up of 4, 5 or 6 sided cells ($\frac{1}{40}$ to $\frac{1}{60}$ inch across) separated by walls ($\frac{1}{150}$ to $\frac{1}{300}$ inch thick), and filled with calcite, which weathers out leaving a very brittle plate; the third or outer layer has a system of large vessels, and the front of minute veins already described.

The [S*alina Upper gray shales* (Scalent gray marls of Rogers), are seldom sufficiently well exposed to be studied in detail; but they agree in character with Vanuxem's description in middle New York, of rather soft, yellowish or drab and brownish colored shale and slate beds, both argillaceous and calcareous; including in Perry county more compact strata, which are hard. In Centre township they are apparently from 200′ to 250′ thick and make the slope of the ridge of No. VI limestone and part of the flat land in the valley at its foot, as far as the little outcrop ridge of Landibsurg sandstone. Owing to their softness they are seldom exposed, and no good sections in this district have been obtained. They contain no valuable mineral in Pennsylvania, but in New York they furnish the brine springs and gypsum beds, which have suggested the name of Salina for the formation.

They are almost barren of *fossils*; only two or three species having rewarded a considerable amount of research; and of these only one occurs in any quantity, namely *Leperditia alta.* This has been found in few places (for example near Buffalo mills, Saville township) abundantly in the Lower Salina red shale; also in the Variegated shales; and becomes exceedingly abundant in their upper layers, whole slabs being completely covered with the casts. But as the Salina Upper gray beds afford few opportunities for examination all that is known about this fossil is that it runs up into and through the bottom massive limestones of No. VI, but not higher. It is Vanuxem's *Cytherina;* see his report page 99. Professor Hall describes in his report of 1844 eight species from the whole formation; seven of them at Newark, therefore probably in the Salina

Lower. The eighth, a *Eurypterus* from Williamsville, Erie county, is probably in the Salina Middle or Upper, as the Salina Lower red is said not to be found west of the Genesee river. We have therefore this fossil, the *Leperditia*, and the *Beyrichia*, both of Lower Helderberg type, passing down apparently together through the Salina towards its bottom.


CII.
No. Va, Clinton fossil ore outcrop lines in Snyder and Mifflin Cos. C.E. Billin.
REPORT OF J.H. DEWEES: F. PLATE A
SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA
MAP OF THE OUTCROPS
of the
FOSSIL IRON ORE BEDS
of the
CLINTON FORMATION. No. V.
in the valley between
JACKS and EAST SHADE MT.
IN SNYDER AND MIFFLIN COS. PA.
compiled by
C.E. BILLIN
UNION COUNTY
SNYDER COUNTY
MIFFLIN COUNTY
JUNIATA COUNTY
L. LEWISTOWN
S. SUNBURY
N. NORTHUMBERLAND
Scale 4 Miles to One Inch.
Reduced to 8 miles.
Susquehanna
PHILA AND ERIE R.R.
SELINSGROVE
KRATZERVILLE
NEW BERLIN
SMITHGROVE
FREEBURG
MIDDLEBURG
PAXTONVILLE
BEAVERTOWN
ADAMSBURG
TROXELVILLE
Jack's Mountain
Shade Mountain
Outcrop
BANNERVILLE
BELLTOWN
DECATUR
WAGNER
MAITLAND
LOGAN
KISHICOQUILLAS VALLEY

Chapter LVIII.

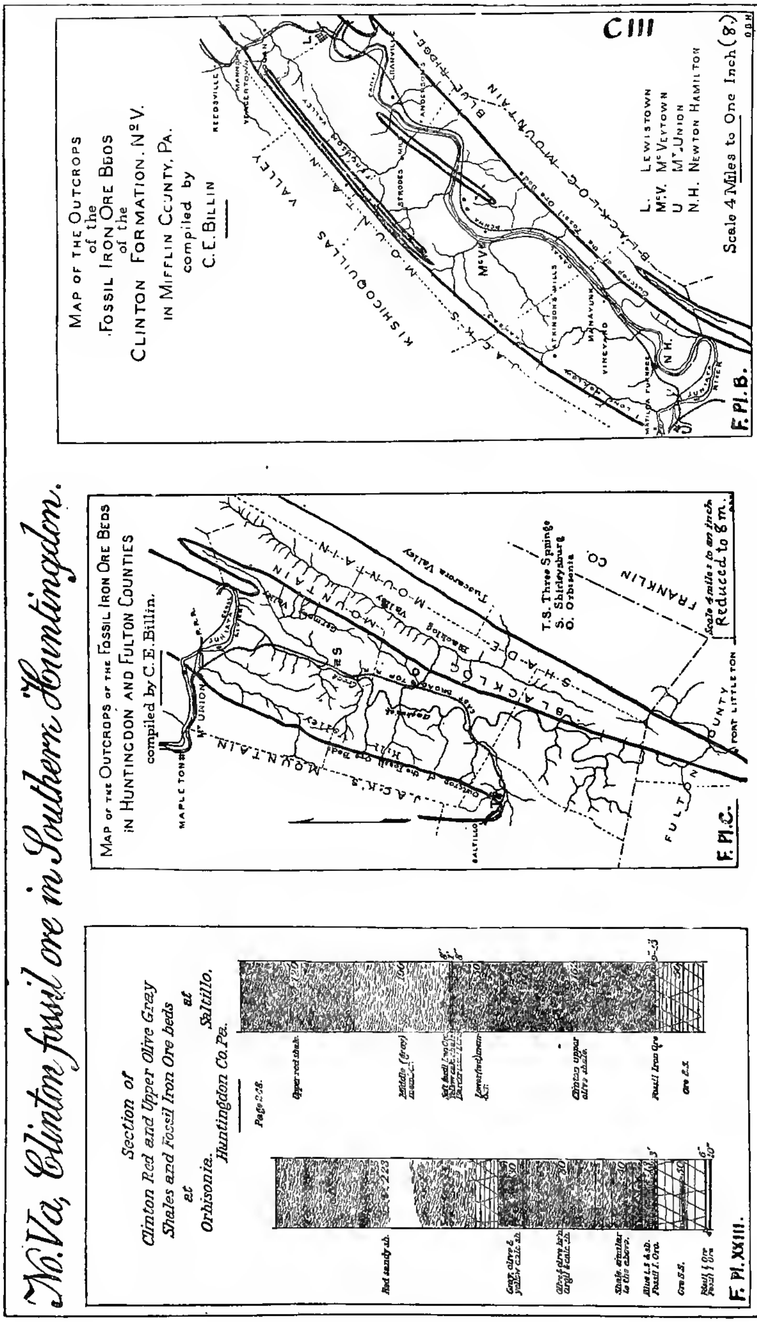
No. V, on the Middle Juniata.

It has been already said that the long triple middle group of mountains of No. IV, Shade mountain, Blue ridge and Black Log, extending from the Susquehanna river near Sunbury to Fort Littleton in Fulton county, within 25 miles of the Maryland line, is entirely surrounded or fringed with Clinton and Salina outcrops containing fossil ore beds.

These ore beds have been wrought to some extent, along the south side of Shade mountain in Juniata county, and to a much greater extent along the north foot of Shade mountain in Snyder county, especially at Middleburg, Beavertown, and Adamsburg. Still more extensive workings have been carried on on the west side of Black Log, all the way from Newton Hamilton past Shirleysburg and Orbisonia in Great Aughwick valley. Orbisonia, in front of Rockhill gap through Black Log mountain, is the principal center of this mining industry. The ore beds have been traced to the south end of the mountain, and back again along the east foot of West Shade mountain past Shade Gap to Juniata county, and along this outcrop mining operations have lately become of considerable importance. In the main valley of the Juniata, between Lewistown and Newton Hamilton, many openings have been made, but not so much mining done on this southeast side of the valley. The river Juniata has a very tortuous course, making two sets of bends, the one set far into the middle of the valley, the other set cutting into the foot of the mountain, so as to expose the Clinton rocks.

The Lewistown Valley.

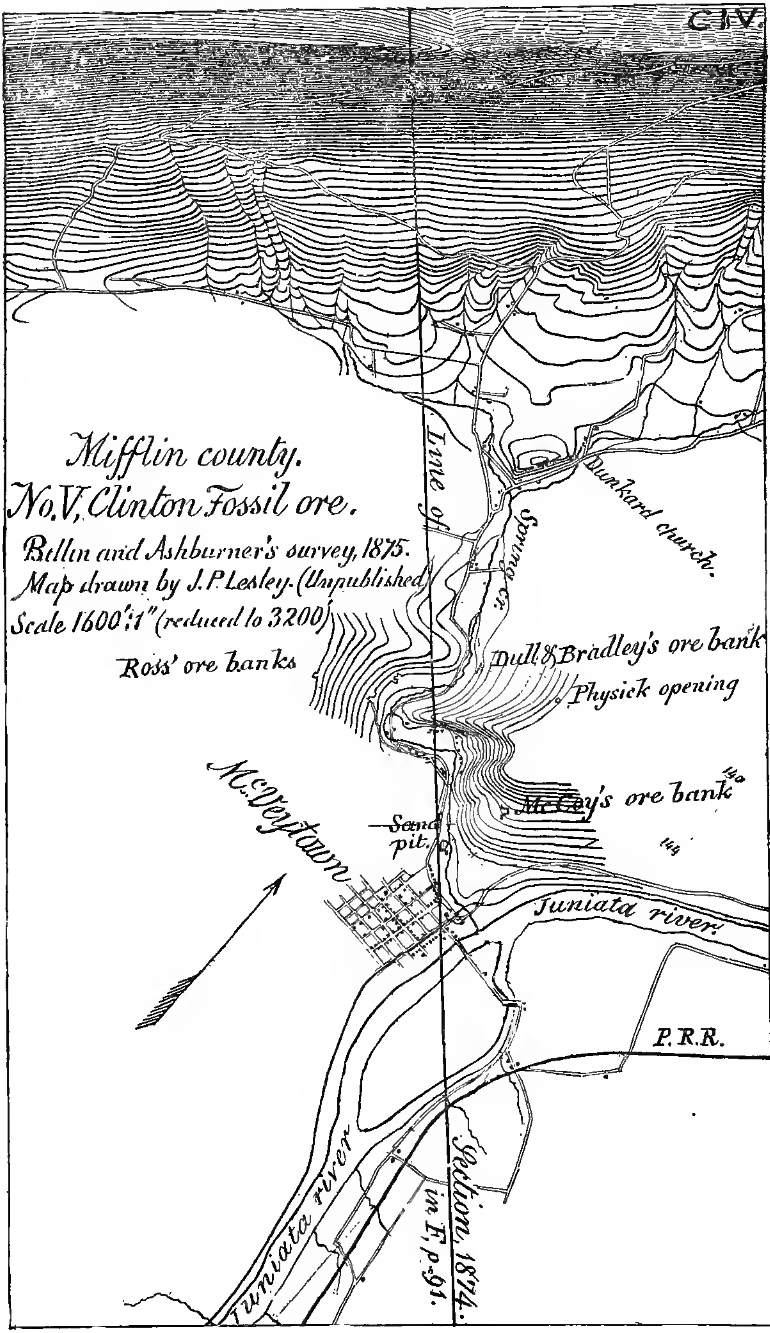
This middle Juniata valley, in Mifflin county, with its comparatively dense population, and numerous mines of


No. Va, Clinton fossil ore in Southern Huntingdon.
Map of the Outcrops of the Fossil Iron Ore Beds of the Clinton Formation. No. V. in Mifflin County, Pa. compiled by C. E. Billin
C III
L. Lewistown
McV. McVeytown
U McUnion
N.H. Newton Hamilton
Scale 4 Miles to One Inch (8.)
F. Pl. B.
Map of the Outcrops of the Fossil Iron Ore Beds in Huntingdon and Fulton Counties compiled by C. E. Billin.
T.S. Three Springs
S. Shirleysburg
O. Orbisonia
Scale 4 miles to an inch Reduced to 8 m.
F. Pl. C.
Section of Clinton Red and Upper Olive Gray Shales and Fossil Iron Ore beds at Orbisonia. at Saltillo. Huntingdon Co. Pa.
Page 238.
F. Pl. XXIII.

fossil iron ore and glass sand, is continued southward as Great Aughwick valley into Fulton county; and northeastward through Snyder county to the forks of the Susquehanna at Sunbury; and so onward as the valley of the North Branch of the Susquehanna. Consequently, Bloomsburg in Columbia, Danville in Montour, Centreville on Penn's creek on the Snyder-Union county line, Bannerville near the Snyder Mifflin county line, Decatur, Logan, Lewistown, McVeytown, Mount Union, in Mifflin county, and Scottville in Huntingdon county are places which all occupy about the same relation to the geological outcrop of No. V which runs along the south slope of Montour's ridge and Jacks mountain for 115 miles.

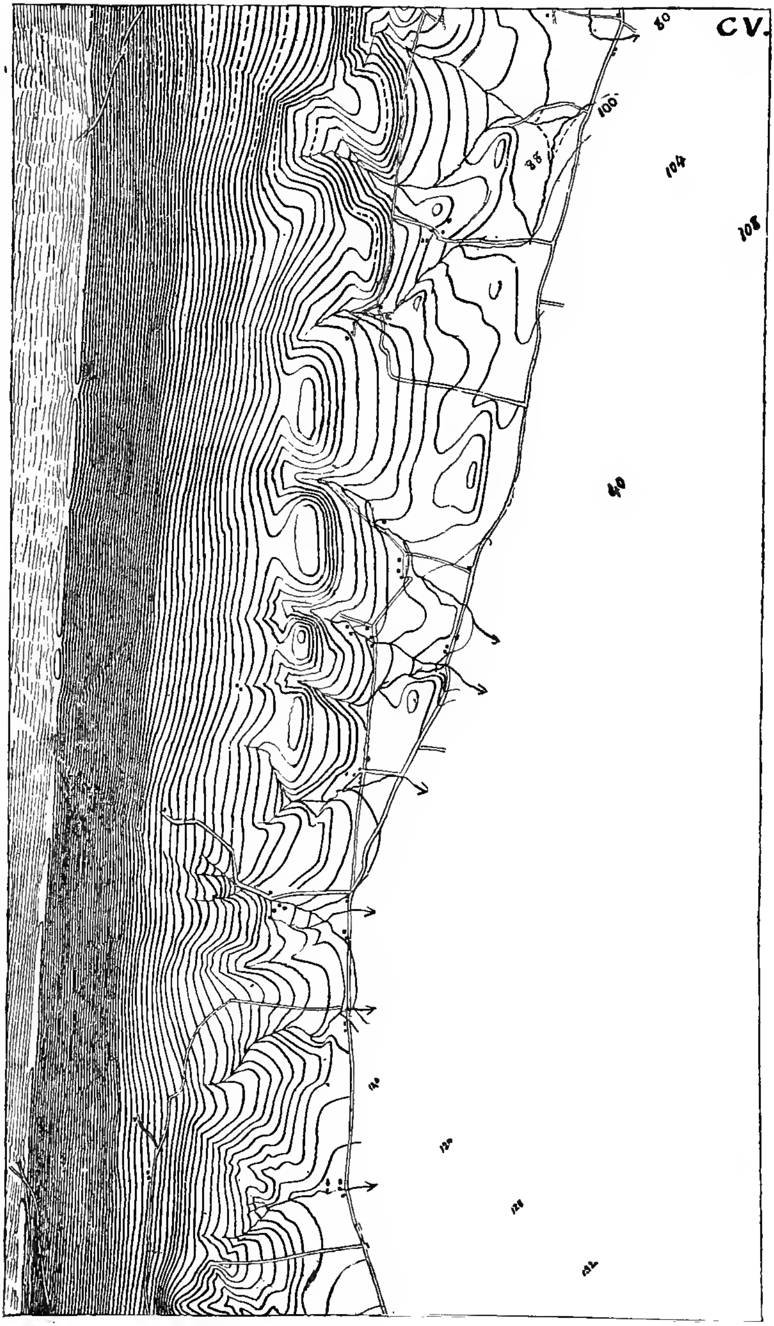
For this distance the Juniata valley proper may be said to extend in a gentle curve not more than five miles wide through Mifflin county between two nearly continuous ranges of mountains of No. IV; having on the southeast, Black Log, Blue Ridge and Shade mountain, and on its northwestern side Jack's mountain and Montour's ridge. The valley is everywhere, geologically considered, a synclinal trough or basin, with formation No. IV deeply buried beneath formations V, VI, VII, and VIII. If we could uncover formation No. IV by scooping away from the valley the upper formations we would find the synclinal trough more simple in its form than the exhibitions at the present surface would lead the observer to suppose. One or two gentle undulations in No. IV no doubt exist, running lengthwise of the valley; but being at least 2000′ thick and very massive and hard, as exposed in the gaps of the mountains on each side of the valley, it has resisted lateral compression and been merely bent into a wide shallow trough with sides rising at an angle of 45° more or less. (See the Lewistown section, F, 49.)* Not so however, with the overlying soft formations V, VI, VII and VIII. These have been held firmly between the rising sides of the great sand formation No. IV, and have been squeezed into in-

*The McVeytown Section, F, 91, shows four closely compressed basins and three sharp rolls at the surface, but a gently undulated nearly flat attitude of No. IV at the depth of 4000′.


C IV.
Mifflin county.
No. V, Clinton Fossil ore.
Bellin and Ashburner's survey, 1875.
Map drawn by J. P. Lesley. (Unpublished)
Scale 1600': 1" (reduced to 3200')
Ross' ore banks
Line of
Spring cr.
Dunkard church.
Dull & Bradley's ore bank
Physick opening
McCoy's ore bank
140
144
McVeytown
Sand pit.
Juniata river.
P. R. R.
Juniata river
Section, 1874.
in F, p. 91.

numerable folds, anticlinal and synclinal, small arches and small basins. And this has taken place to the greatest extent where the valley is narrowest and the two bounding mountains come nearest together, that is, in Mifflin county, the geological map of which (pl. 41 of the Hand Atlas) shows these folds by the yellow and blue stripes representing the outcrops of the Oriskany sandstone No. VII, and the Lewistown limestone No. VI; but it does not show the far greater number of smaller folds in the two red side belts, representing the outcrops of Salina and Clinton No. V. Isolated, long, narrow-pointed synclinal strips of Marcellus and Hamilton (bottom formations of No. VIII) are also represented on the map, but not the folds into which these also have been pressed.

Now, the general erosion of the country has reduced the valley, as compared with the mountains which bound it, to a general level, by cutting off the tops or crests of all the folds in all these formations, but still leaving the harder outcrops running along the bed of the valley as low ridges, some dipping one way, that is, southeast, and an equal number dipping the other way, that is northwest. Every variety of topography beautifies the valley and illustrates its geological structure. Innumerable outcrops of hard and soft rocks run side by side, some in valleys, some on the slopes, some along the tops of the low ridges, none of which rise more than 300′ above the level of the river. In among these outcrops, crossing them, cutting through them, and exposing them to view in many places, flows the most beautiful river of Pennsylvania; at an elevation of about 600′ above tide where it issues from Jacks Narrows at Mount Union, and about 500′ where it leaves the valley opposite Lewistown to enter the Long Narrows between Blue Ridge and Shade mountain. And here for nine miles in these Long Narrows the river has selected for its channel a deep synclinal basin of the Clinton red rocks of No. V; the mountain walls of this long and picturesque defile being made by the lower beds of V, reposing with their steep dips against the sides of a trough of white Medina sandstone No. IV, the outcrops of which, running along the two crests look down into the lonely gorge.


CV.
80
100
88
104
108
40

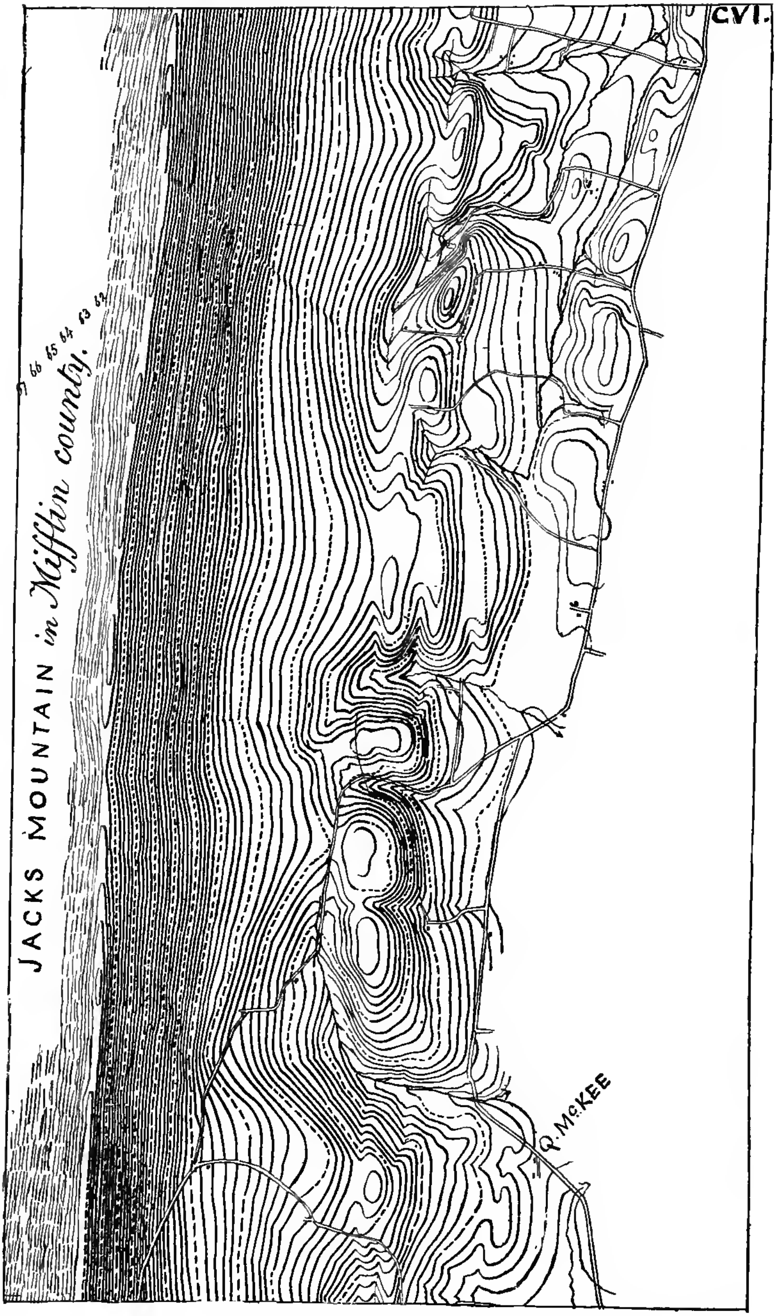
Where the river turns from Lewistown to cut across the dying anticlinal of Shade mountain and enter the southwest mouth of the Long Narrows, a fine bluff section of the red rocks of V has been obtained as follows (F 50, Fig. 5):

Long Narrows section, South of Lewistown.

Salina Upper and Middle shales, visible, ...		508′
Salina Lower (Bloomsburg) red shale, ...		260′
Clinton Upper lime shales, with limestones 2″ to 12″ thick, ...		160
Fossil ore shales, with traces of Sand Vein Ore, .		50′
Ore SS. { argillaceous, parted by small beds of sandy shale, ...	10′	22
Ore SS. { massive, with cleavage planes 6″ to 12″ apart,	12′	
Sandy shale, ...		24′
Danville ore rock with traces of ore, . . .		10′
Clinton Lower lime shales, with many fossiliferous limestone layers, from 1 to 6 inches thick, ...		36′

Contour map of South Slope of Jack's mountain.

The northwest side of the Juniata or Lewistown valley however has furnished to the Survey its instrumental sections, made chiefly in 1875 by Mr. Dewees and his assistants during the elaborate topographical survey of the Southern slope of Jack's mountain from Logan's gap southwestward past Lewistown and McVeytown to Mount Union at Jack's Narrows. A contour line map of this survey was prepared for Report F, but not published with it, and is here inserted on a reduced scale as a typical expression of the peculiar topography of the upper or No. V slope of every mountain of No. IV in this part of the state. It shows the character of the drainage of the slope, from the crest of the mountain to its foot, across the outcrops of the Lower, Middle and Upper Clinton formations, as they successively occupy lower positions descending the slope. The brooks, cutting deeper and deeper into the foot slope of the mountain, through the fossil ore beds, have given opportunities for mining them at water level, with the soft ore above the gangway and the hard ore beneath it;


CVI.
JACKS MOUNTAIN in Mifflin county.
Q. McKEE

and the position of the mouths of the gangways are shown upon the map.*

No. V at Logan's gap, Plate LXXXI.

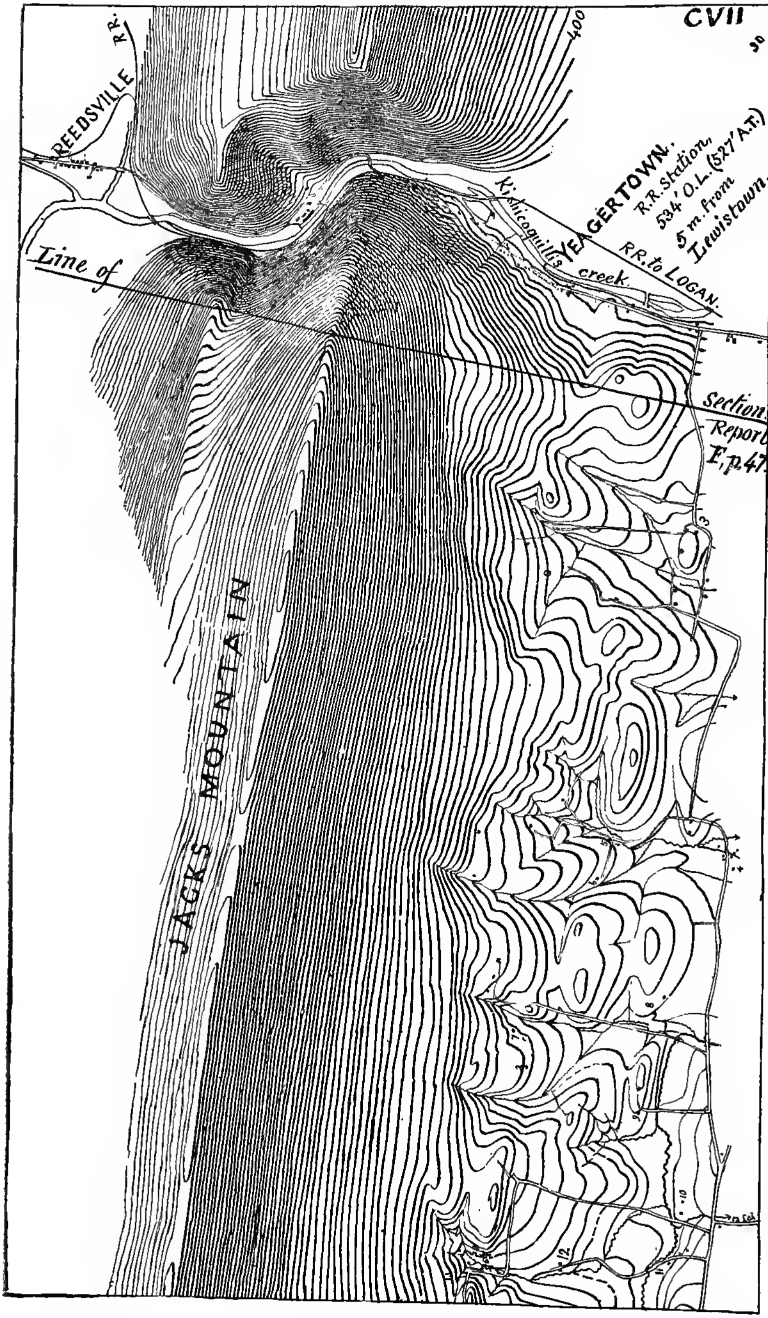
The section from Reedsville southward through Logan gap, past Yeagertown, in the first synclinal fold and across the first anticlinal fold to Logan furnace, one of the most complete and carefully differentiated sections made by the Survey is represented (looking east) in plate LXXXI (p. 792, below) taken from Report F, p. 47).

The following summary of the section will show the relation of the Salina and Clinton beds of V to the underlying Medina and Oneida rocks of the mountain and the Hudson river, Utica, and Trenton formations on which they rest. The letters placed before the names are those which in the section designate the groups as arranged at the time of publishing the report :

Summary of the Logan Section.

j. Salina gray shale,		164′
k. Salina Variegated shale,	423′	348′
l. Logan limestone,		3½′
m. Logan shale,		72′
n. Salina Upper red shale,		432′
o. Salina Upper lime shale,		326′
p. Salina Lower red shale,		272′
q. Clinton Lower lime shale,		251′
r. Clinton Upper olive shale,		
s. Ore sandstone and ore beds,		38′
t. Clinton Middle olive shale,		178′
u. Iron sandstone,		7′
v. Clinton Lower olive shale,		571′
w. Medina white sandstone,		820′
x. Medina red sandstone and shale,		1280′
y. Oneida red conglomerate,		309′
z. Oneida gray sandstone,		313′

*I have already refered to this map in one of the chapters on Formation IV above. I place plates CIV, CV, CVI, CVII here because the intention of the local survey was not so much to get a study of the slope of the mountain as to determine the relation of the fossil ore beds which outcrop upon it to the anticlinal and synclinal rolls which traverse its foot hills and the adjoining valley on the south. The meaning of this survey map can only be understood by consulting Ashburner's sections reproduced on a reduced scale in Plates LXXXI, LXXXII, LXXXIII, LXXXIV on pages 640, 642, 644, 646, of Vol. 1, above.


CVII
400
REEDSVILLE R.R.
YEAGERTOWN.
R.R. Station,
534' O.L. (527' A.T.)
5 m. from
Lewistown.
Kishicoquillis creek.
R.R. to LOGAN.
Line of Section.
Report F, p. 47.
JACKS MOUNTAIN

aa.	Hudson river slates,	937′
bb.	Utica Upper gray slates,	210′
cc.	Utica Middle black slate,	302′
dd.	Utica Lower gray slate,	855′
ee.	Trenton limestone, etc., visible,	320′

The nomenclature adopted for this section and used in the report on the fossil ore district of the Juniata (F, 1878), does not agree with the nomenclature adopted in reports upon other districts.* It is slightly modified in the summary table given above, and wholly changed in the detailed section to be given directly. It is in fact impossible to invent any entirely satisfactory set of names for groups of beds in formations which vary everywhere in color, in thickness, and in the alternate arrangement of their constituent parts. The condition of things connected with the material bearing currents, the depth of water, and the groupings of animal life, it is impossible to make out with any distinctness; while the erosion of the anticlinals separating the numerous areas of preserved strata, while it has afforded unexampled facilities for the examination of their outcrops, has at the same time placed insuperable obstacles in the way of any attempt at a particular and precise identification of the minor groups in the different areas. Every group of these rocks varies incessantly along every one of its outcrops; and when a group sinks at one side to descend beneath a synclinal with a given character it reappears at the surface on the opposite outcrop of the trough so greatly changed and so confused at its upper and lower limits with the group above and the group below it that nothing more than its identification as a whole can be established. If local geographical names were given to the groups the confusion would be only the more apparent, and the publication of such a nomenclature would give rise to future debates, embarrasing to the field worker, and only important to those who assign an undue value to mere words.

*In Report F, group j, was called Water Lime shale, but it evidently corresponds to the Salina Upper gray shale underlying the limestones of VI. In Report F, the groups l and m were provisionally called Niagara limestone and Niagara shale, but for no other reason than that they intervene, between undoubted Salina Variegated shales, and what was then known as

Bloomsburg red shale in Mifflin Co.

We receive no aid from Palæontology, because of the commingling of species which in New York outcrops characterize the Clinton and the Lower Helderberg (Lewistown) deposits ; but what is most inconveniently felt is the absence of any well-defined Niagara horizon. For if in middle Pennsylvania the Niagara limestone with its characteristic fossils came in between the Clinton and the Salina, we could use it to separate these formations beyond the possibility of mistake. As the case stands, Clinton strata pass upward almost insensibly into Salina strata ; and that too in so many different ways in different places, that we are obliged to look upon the great Salina Lower (Bloomsburg) red shale mass as our best guide. It is however a reliable guide only when taken as a mass ; for in its constituent elements it is subject to as many and the same kind of variations as the other formations. We have seen in Perry county and in Montour county that this mass of red shale is taken as a unit from bottom to top. But here in Mifflin county, where it has been studied bed by bed. we see it in a quite different light ; sub-divided into many small groups of alternate red and olive shale, like the Salina Middle Variegated shale ; and below it for many hundreds of feet occur other groups of red shales ; and far down a mass of red shale 90′ thick ; so that its value as a guide to classification is almost lost. Upon it lie more than 400′ of Salina Variegated shales ; and about 70′ higher lies a peculiar thin limestone stratum $3\frac{1}{2}'$ thick, outcropping near Logan furnace, to which I have therefore given the local name of the Logan limestone.*

Clinton red shale, but what is now well recognized as Salina Lower (Bloomsburg) red shale. In Report F, groups n and p were called Clinton Upper and Lower red shale, and the large mass of limy gray shales separating the two was called Clinton Upper lime shale. The uppermost of these three groups must now be considered Salina Lower (Bloomsburg) red shale. The middle one corresponds to Clinton Upper lime shale; and the lower one must be extended downward nearly 100′, and be called Clinton Lower lime shale. What remains between this and the Ore sandstone will then be Clinton Upper olive shale.

*In the survey of the district, this limestone and the shales beneath it were suspected to represent the Niagara, and received provisionally and

On top of the Salina Middle Variegated shales in the vertical cross section at Logan furnace are seen 164′ of *Salina Upper gray shales ;* the whole amount of which is seen to be, when the outcrop is followed and measured elsewhere, 470′ ; including however in its upper part limestone beds which are undoubtedly referable to the Water Lime group (the cement beds of No. VI) on top of which lie the massive Lewistown limestone No. VI, 185′; and over this, lime shales, 140′; over which again come 205′ of sandy shales belonging to the Oriskany No. VII ; and then the Oriskany sandstone itself 110′; above which the Corniferous shales of the Upper Helderberg formation, 93′ ; and on top of all the regular Upper Helderberg limestone, 40′. All these super-Salina formations will be described in succeeding chapters. It is only necessary to remark here that the Salina Upper gray shales pass insensibly or are mixed with the Water Lime beds in such a way as to make it impossible to draw hard and fast lines of demarkation between them.*

No. V, at Lewistown, plate LXXXII.

The following vertical section of Salina and Clinton beds was measured between Logan furnace and Logan gap in Jack's mountain, east of Lewistown, in Mifflin county. Characteristic specimens were taken from each bed and are preserved in the museum of the survey ; were labeled and catalogued in Report O ; and their numbers may be referred to by consulting Report F, pages 51–54.

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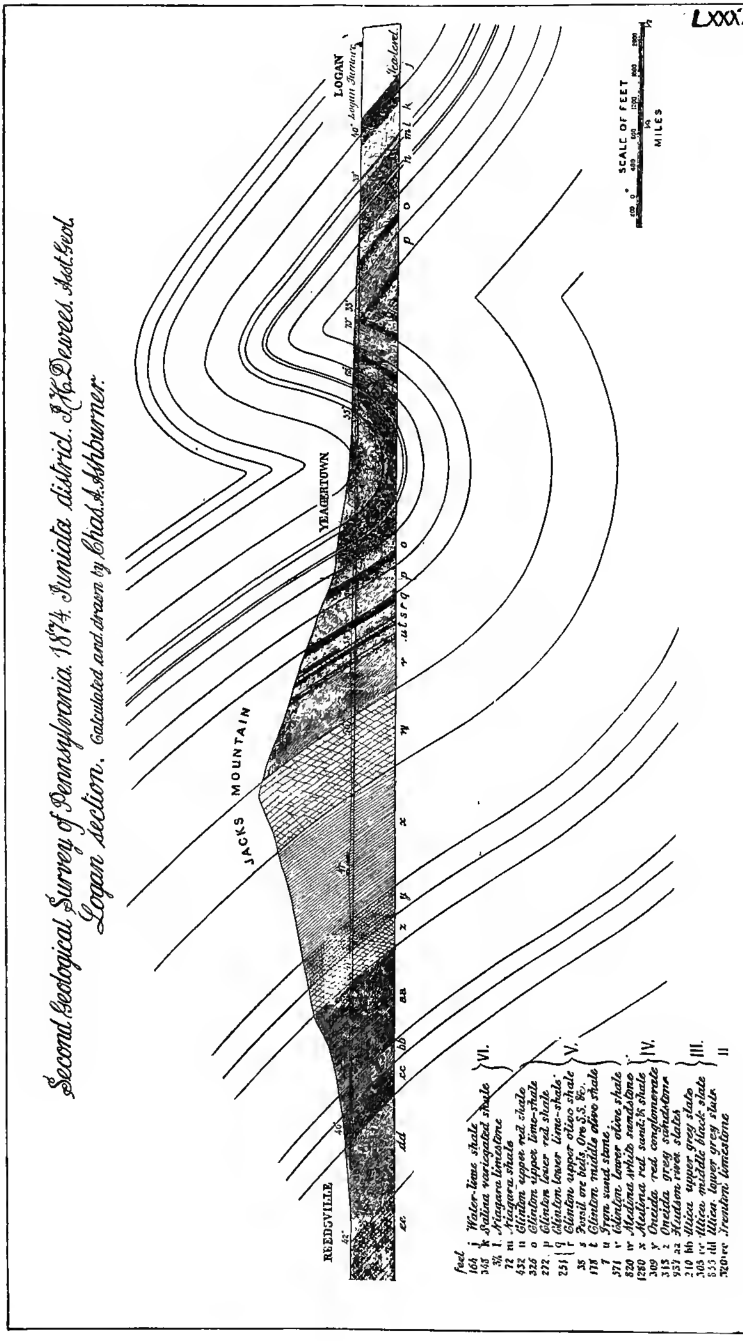
doubtfully that name, see page 52, F. The error is obvious; for any Niagara rocks present in the district must underlie the Salina Lower red shale.

*In England there has been a controversy over the connection between the Wenlock (Niagara) and the Ludlow (No. VI) formation, some contending that there is a break of nonconformability between them ; and this assertion is supported by the apparent absence of our American Salina formation in England. Evidently in Pennsylvania there is no break in the series from the bottom of No. V to the top of No. VI ; unless the geologist chooses to consider every variation of thickness, and every local disappearance of a stratum or group of strata in the series, to be a plane of nonconformability ; which would only be an admissible supposition on the theory of shallow water and local temporary emergencies of dry land. Nothing of this sort appears in our survey of this district ; and the theory of deep water is the more probable.


LXXXI
Second Geological Survey of Pennsylvania. 1874. Juniata district. J. H. Dewees. Asst. Geol.
Logan section. Calculated and drawn by Chas. A. Ashburner.
LOGAN
Logan Furnace
YEAGERTOWN
JACKS MOUNTAIN
REEDSVILLE
SCALE OF FEET
MILES
feet
164 j Water-lime shale
343 k Salina variegated shale
3½ l Niagara limestone
72 m Niagara shale
432 n Clinton upper red shale
326 o Clinton upper lime-shale
272 p Clinton lower red shale
251 q Clinton lower lime-shale
r Clinton upper olive shale
35 s Fossil ore beds, Ore S.S. &c.
178 t Clinton middle olive shale
7 u Iron sand stone
571 v Clinton lower olive shale
820 w Medina white sandstone
1280 x Medina red sand. & shale
309 y Oneida red conglomerate
313 z Oneida grey sandstone
957 aa Hudson river slates
210 bb Utica upper grey slate
303 cc Utica middle black slate
633 dd Utica lower grey slate
320 ee Trenton limestone
VI.
V.
IV.
III.
II.

Logan Section, Mifflin County.

Salina gray shales, 166′.

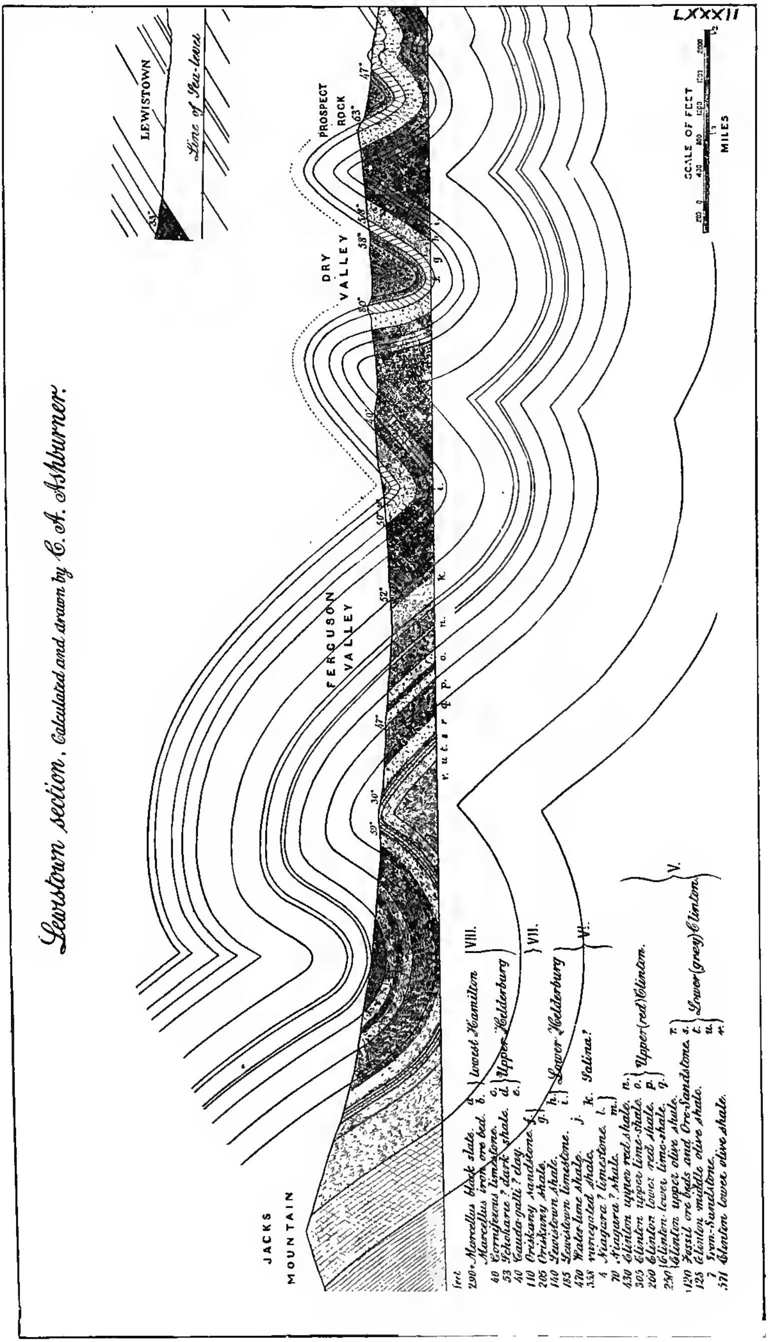
Limestone, slightly argillaceous, dark blue, alternating with dove-colored lime shale, ...	19.5′
Limestone, argillaceous, somewhat hydraulic, dove-colored, with lime shales, ...	45.5′
Lime shales, soft, dove-colored, in the middle of which lies a hard, bluish black, limestone stratum 3′ thick,	26.0′
Limestone beds, not well exposed, ...	54.6′
Limestone, argillaceous, dark grayish blue, square fracture, laminated, ...	7.2′
Limestone, shaly, not well exposed, ...	13.6′

Salina Variegated shale, 422′

Lime shale, dark gray, argillaceous, ...	13.6
Lime shale, sandy, fragile, yellowish brown, . . .	6.5′
Lime shale, dark gray, argillaceous, .	21.5′
Lime shale, dark gray, alternate clayey and sandy, . .	6.5′
Lime shale, dark gray, friable, uneven fracture, . .	6.5′
Lime shale, dark gray, clayey, square fracture, alternate with hard yellow sandy lime shales, ...	4.6′
Lime shales, olive, argillaceous, ...	8.4′
Saudstone, argillaceous, hard, yellow, thin layers, . .	5.8′
Lime shale, hard, argillaceous, dark gray with occasional sandy shales, ...	20.2′
Clay shale, dove-colored, alternate yellow sandy shale, .	7.8′
Limestone, argillaceous, dark gray, heavy, even fracture,	4.6′
Clay shales, olive, ...	52.6′
Olive shales, not well exposed, ...	125.0′
Red shale, ...	5.0′
Lime shale, sandy, compact, yellow, ...	2.5′
Red shale and olive shale in alternate layers 3″–6″, . .	5.7′
Limestone, argillaceous, massive, dark blue, even fracture,	2.0′
LOGAN LIMESTONE, heavy with iron, fossiliferous, .	1.5′
Limestone, heavy, light blue, even fracture, . . .	2.0′
Olive red and yellow, soft snales, mostly olive, . .	70.0′

Salina (Bloomsburg) red shale, 432′

Red shale, ...	191.7′
Red and olive shale alternating, ...	35.4′
Red shale, ...	35.0′
Olive shale, ...	4.0′
Red shale with occasional olive layers, ...	70.8′
Red shale, ...	47.8′
Olive shale, ...	5.9′
Red shale with thin layers of olive, ...	4.4
Red shale (hard) and olive shale alternations, ...	38.0′


LXXXII
Lewistown section, Calculated and drawn by C. A. Ashburner.
JACKS MOUNTAIN
FERGUSON VALLEY
DRY VALLEY
PROSPECT ROCK
LEWISTOWN
Line of Sea-level
59° 30° 47° 52° 50° 40° 80° 58° 58° 63° 47° 33°
r. u. t. s. r. q. p. o. n. k. i. f. g. h. i.
feet
290+ Marcellus black slate. a.
Marcellus iron ore bed. b. } lowest Hamilton } VIII.
40 Corniferous limestone. c.
53 Schoharie? dark shale. d. } Upper Helderburg
40 Cauda-galli? clay. e.
110 Oriskany sandstone. f.
205 Oriskany shale. g. } VII.
140 Lewistown shale. h.
185 Lewistown limestone. i. } Lower Helderburg
470 Water-lime shale. j.
358 variegated shale. k. Salina? } VI.
4 Niagara? limestone. l.
70 Niagara? shale. m.
430 Clinton upper red shale. n.
305 Clinton upper lime-shale. o.
200 Clinton lower red shale. p. } Upper (red) Clinton.
250 Clinton lower lime-shale. q.
Clinton upper olive shale. r.
120 Fossil ore beds and Ore-Sandstone. s.
125 Clinton middle olive shale. t. } Lower (grey) Clinton. } V.
7 Iron-Sandstone. u.
571 Clinton lower olive shale. v.
SCALE OF FEET
MILES

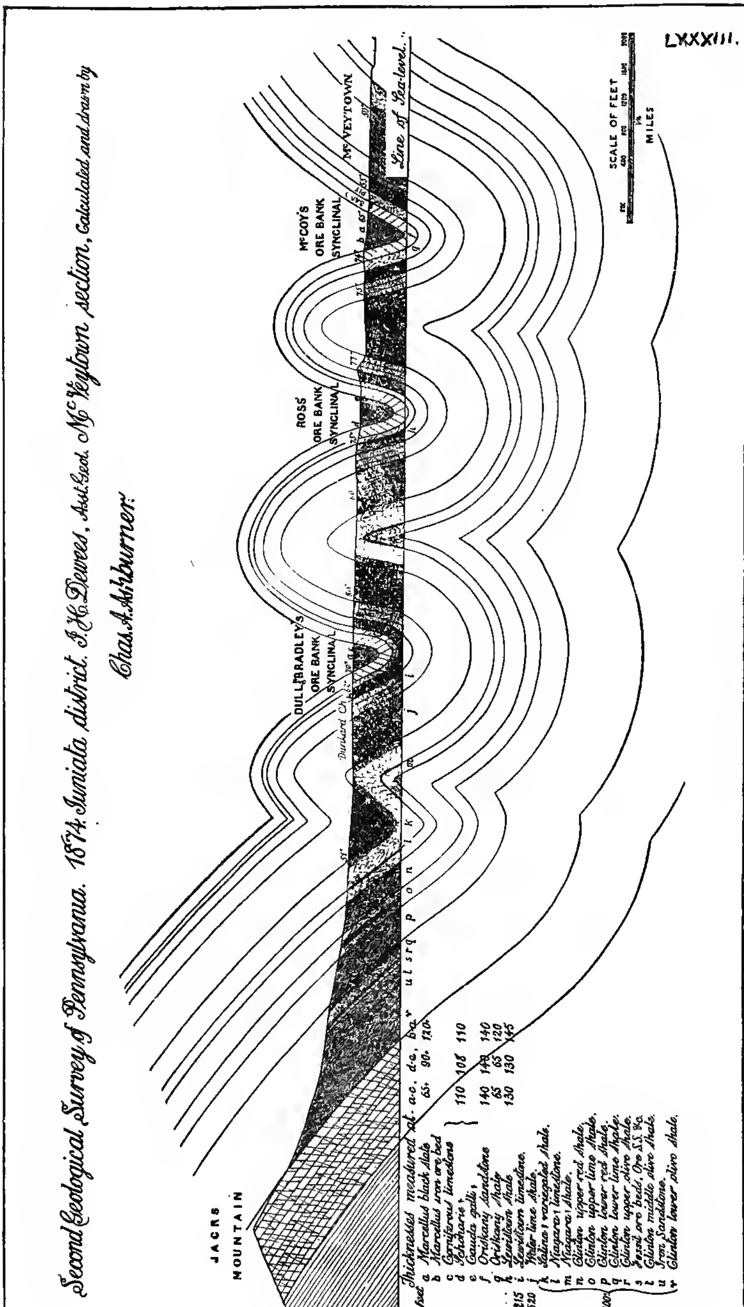
Clinton Upper lime shales, 325′

Yellow, red and green shales alternating,	62.6′
Sand shale, yellow, heavy,	3.6′
Sand shale, yellowish, olive,	3.5′
Sand shale, lead colored,	8.8′
Limestone, sandy, blue,	1.0′
Olive shale, heavy, somewhat sandy,	11.4′
Sandy shale, heavy, lead gray,	18.5′
Limestone,	1.7′
Sand shale, light olive,	9.8′
Shale, heavy, somewhat sandy, lead colored, slightly yellowish, alternating with red and olive shales,	17.6′
Red and olive shales, sandy,	10.7
Limestone, fossiliferous,	2.7′
Olive shale,	9.8′
Olive gray shale, sandy,	115.7′
Sand shale, pinkish gray,	4.5′
Sand shale, olive, soft,	43.6′

Clinton Lower lime shale, 523′

Sandstone, yellow, thin layers, separated by lime shales,	12.5′
Olive sand shale,	4.5′
Red shale,	6.2′
Olive shale, soft (light green),	4.5′
Red shale,	8.0′
Olive shale (yellowish green),	4.5
Red shale,	8.9′
Olive shale, soft, alternating with a fragile limestone,	12.5′
Olive shale, still softer,	18.7′
Olive and yellow shale alternating with lime shale,	81.9′
Red and olive shale alternately,	15.9′
Olive shale, tint red,	2.7′
Red shale,	66.3
Red shale, harder than last,	24.9′
Dark, heavy shale,	21.0′
Lime shale, dark, sandy, alternating with dark olive clay lime shales,	70·0′
Olive shale,	5.2′
Sandstone, limy, blue,	1.7′
Olive shale,	4.3′
Olive and green shale,	37.0′
Olive shale, containing thin layers of gray sandstone and a 6″ layer of limy sandstone,	*.9′
Olive sand shales, soft,	60.6′
Limestone, blue, fossiliferous,	.2
Olive and yellow, gray, sand shales,	25.8′
Gray and olive sand shales,	3.4
Limestone,	.3′
Limestone in two layers,	.6′

*There is some mistake here in the published record.


LXXXIII.
Second Geological Survey of Pennsylvania. 1874. Juniata district. J. H. Dewees, Asst. Geol. McVeytown section, Calculated and drawn by
Chas. A. Ashburner.
JACKS MOUNTAIN
DULL & BRADLEY'S ORE BANK SYNCLINAL
Dunkard Cr.
ROSS ORE BANK SYNCLINAL
McCOY'S ORE BANK SYNCLINAL
McVEYTOWN
Line of Sea-level.
SCALE OF FEET
MILES
Thicknesses measured at a-c. d-e. b-a.
a Marcellus black shale
b Marcellus iron ore bed
c Corniferous limestone
d Schoharie
e Cauda galli
f Oriskany sandstone
g Oriskany shale
h Lewistown shale
i Lewistown limestone
j Water lime shale
k Salina variegated shale
l Niagara limestone
m Niagara shale
n Clinton upper red shale
o Clinton upper lime shale
p Clinton lower red shale
q Clinton lower lime shale
r Clinton upper olive shale
s Fossil ore beds, Ore S.S. &c.
t Clinton middle olive shale
u Iron Sandstone
v Clinton lower olive shale

Olive, shales,	1.0′
Limestone, blue, fossiliferous,	.2′
Olive shales,	18.9′

Ore sandstone group, 38′

Fossil iron ore, soft at the surface,	1.3′
Olive shale,	4.0′
Fossil iron ore, at the surface,	1.3′
Sandstone, limy, gray, tough, with thin shale partings,	31.0′

Clinton Upper olive shale. 178′.

Olive shale,	8.2′
Sandstone, hard, grayish blue,	13.1′
Olive shale,	9.6′
Olive, clay shale,	1.6′
Limestone, gray, blue, fossiliferous, ferriferous,	.6′
Sandstone, hard, blue, in thin layers with gray shale partings,	9.8′
Limestone, blue, fossiliferous,	1.6′
Purple shales,	12.3′
Olive shales, soft,	3.3′
Olive green shale,	1.6′
Purple shale, soft,	.8′
Purple sandy shale, dark, soft, ferriferous with thin sandstone partings,	18.0′
Dark green and olive shales,	53.3′
Limestone, fossiliferous,	.2′
Gray shale, dark, hard, with thin sandstone partings,	24.6′
Olive shale, dark, heavy,	19.7′

Iron sandstone, 7′.

Sandstone, hard, ferruginous,	6.6′

Clinton Lower olive shale, 571′.

Olive shale, heavy with alternate layers of hard gray sandstone and soft sandstone,	25.4′
A thin layer of hard gray iron sandstone,	25.2′
Dark green and purple shale, alernating with soft sand shale,	90.2′
Dark green and purple shale,	55.3′
Dark green and olive sandy shales,	335.0′
Dark green, very soft shales alternating with soft ferruginous shales,	67.0′

It will be seen by studying the items of the above section how purely artificial its division into groups under their respective names must be; and how infinitely changeable is this whole mass of 2664′ of mud and fine-sand deposits, with occasional thin layers of limestone evidently produced by the animal life of that age, and occasional layers charged with an extra percentage of iron. The distribution of colors, purple, red, blue, yellow, deep green and olive cannot be subjected to any law of human thought; for they were determined locally by the combination of many circumstances incessantly varying as the deposits were gradually spread one upon another.

Only seven fossilferous limestones are mentioned in the section, varying in thickness from 2″ to 2½′ but these merely represent the accidental growth of mulitudes of shells in colonies together for limited spaces of time; and as these species continued to exist in the same sea from the beginning to the end of the age, millions of scattered shells and similar groups of shells could undoubtedly be seen pervading the whole formation if it were transparent to the eye of the observer.

In using this section therefore at other places in middle Pennsylvania, even at places at no great distance from where it was made, the field worker need not look with any confident expectation to finding fossilferous limestone layers at the precise places which they occupy in this vertical section; for no fossilferous limestone layer can be expected to extend to any distance from the place where it is exposed to our view, but some other similar layer will be found at a higher or lower horizon in any other section which may be made; and the same must therefore be true of the fossil ore beds, which are nothing else than such fossilferous limestone layers partly changed into iron ore.

The inhabitation by animals of a sea bottom, whether under shallow or under deep water, continually shifts as deposits are made, just as the occupation of the present surface of the earth by human beings continually varies in place and quantity; especially on great plains where men pursue not a fixed and sedentary but a roving nomadic life. The tribes of shell fish living on the sea bottom recall to the imagination of the palæontologist, the roving tribes of northern Asia, Australia, the Persian and Arabian deserts or the Buffalo plains of the American continent. As southern Africa has its wet and dry seasons, and its scattered population must conform to circumstances by shifting their residence as the rivers and lakes dry up, or are refilled in the rainy season, so the shell fish of Silurian times moved to and fro as the waters were charged here with mud and there with sand, or became now calcareous and then ferruginous, establishing their colonies densely packed together sometimes at one place and at other times elsewhere on the sea bottom. These mutations of zoological history in the remote geological ages can never be subjected to satisfactory scientific research; must forever remain a vague and shifting picture before the imagination of the student. But let him draw therefrom this, if only this one, important piece of knowledge, and carry it with him into every field of his survey, namely, that the best constructed, the most minutely differentiated, the most accurately measured local section, is to be trusted as a guide only in its immediate vicinity; for if it be confided in at distant points it will invariably play the part of an *ignis fatuus*, leading the field worker into bogs of falsehood instead of leading him over the solid ground of truth.

Practical illustrations of this fixed canon of structural geology will now be given before proceeding further, in the two following similar sections, at Mount Union and Orbisonia. The Mount Union section was measured at Jack's narrows, 22 miles southwest of the Logan section. The Orbisonia section was measured at Rockhill gap of Black Log mountain, 15 miles south of the Mount Union section. These two sections are given without subdivision into groups; field workers who use them being permitted to establish for themselves whatever groupings they prefer.

The Mount Union Section (F, page 104).

ORISKANY SANDSTONE NO. VII, upper beds massive, coarse grained, hard, yellow; lower beds softer, argillaceous, and very calcareous, the rock harder here than elsewhere in the district, .	95.0′	377.0
Sandstone strata, yellow and dark, ash-colored, calcareous; passing downwards into beds of mostly yellow, but also purple and pink sandy shales, .	282.0′	

LEWISTOWN lime shale, friable, ... about	18.0′	
LEWISTOWN LIMESTONE No. VI, massive beds, dark-gray, crypto-crystalline, quarried for furnace flux, ... about	35.0′	152.0
Limestone, thin bedded, dark gray layers 1″–2″, .	30.0′	
Limestone, massive, dark gray, alternating with beds of yellow, honeycombed limestone, ...	68.8′	
Lime shale, hard, dove-colored, ...	9.6′	
Lime shale, friable, clayey and sandy, . .	20.8′	
Lime shale, massive, argillaceous, ...	5.6	
Lime shale, friable, argillaceous, ...	49.9′	
Lime shale and limestone alternating, dove-colored, argillaceous, ...	58.5′	
Limestone, friable, clayey, sandy with lime shale,	109.0′	
Strata not exposed, ...	88.4′	425.0
Limestone, dove-colored, argillaceous, containing calcite, ...	23.5′	
Limestone, dove-colored, alternating with cellular limestone and lime shales, ...	27.1′	
Limestone, dark gray, massive, alternating with blue shaly limestone, ...	15.0′	
Limestone, dull gray with calcite, alternating with dove-colored clay lime shale, ...	18.1′	
Lime shale, thin, flakey, ...		19.8′
Limestone, argillaceous, dark gray, massive with calcite, .		25.4′
Limestone, sandy, blue gray, hard, with sandy lime shale partings, ...		37.1′
Lime shales and sand shales, yellow and gray, with veins of calcite, ...		90.7′
Limestone, argillaceous, blue gray, massive, with lime shales and veins of calcite, ...		40.4′
Lime shales and sand shales with sandstone partings, .		33.1′
Purple and green lime shales with some calcite veins, .		33.1′
Lime and sand shales, alternately gray and green, . . .		203.4′
LOGAN limestone, blue, hard, massive, . . .		3.0′
Red, green and bluish gray shales with some limestone partings, ...		53.6′
Gray, laminated lime shale over a mass of alternating blue and olive shales, ...		55.0′
Red and yellow shales, ...		123.5′
BLOOMSBURG red shale, ...		28.5′
Limestone, thin bedded, dark blue, alternating with dove-colored sandy shales, ...		100.5′
Limestone blue and gray alternations with some dove-colored clay lime shale partings, ...		23.0
Olive shales, dark, ...		14.0′
Lime shale, blue, ...		1.0′
Olive shale, dark, greasy to touch, ...		3.0′
FOSSIL iron ore bed, ...		1.3′
Sandstone, shaly, ferruginous, ...		.1′
ORE SANDSTONE, very hard, gray, ferruginous, ...		40.0′
FOSSIL iron ore, hard, ...		1.7′

Sandstone layers, dark, alternating with red and olive shales,	30.4′
Limestone, fossiliferous, sandy layers 2″ to 6″, with red and green shale partings,	2.0′
Sand shales, yellow and green, with thin fossiliferous limestone partings,	56.3′
A sandstone flag, very hard, gray,	5.0′
Purple shale, flags, hard,	19.5′
Limestone, fossiliferous, with gray shale and sandstone partings,	39.0′
Olive shales, dark, alternating with olive flagstones and gray sand shale,	107.9′
Sandy shale, bluish gray, with occasional sandstone layers,	27.3′
Purple and gray shales with occasional sandstone layers,	76.8′
IRON SANDSTONE, gray, ferruginous,	2.0′
Olive shales, dark, with purple and gray alternations,	46.6′
Variegated shales with occasional sandstone layers,	59.5′
Sandy shale, light gray, ferruginous,	12.5′
Sandy shales, yellow, gray and olive,	61.0′
Purple shale with occasional sandstone layers,	16.5
Shales not well exposed lying upon hard speckled, massive sandstone beds of No. IV,	111.5′

The Orbisonia Section, Plate LXXXVI.

ORISKANY SANDSTONE No. VII; upper part ochre, lower part coarse grained iron and lime sandstone,	12.0′
Sandstone, friable, with pebbles size of a pea,	15.0′
Sandstone, coarse grained, more fragile, breaking into irregular shapes, iron-stained; surfaces coated with red hematite. Sometimes an ore bed, very fossiliferous,*	31.0′
LEWISTOWN LIMESTONE No. VI (partly concealed) upper layers shaly, lower layers crystalline limestone,	30.0′
Limestone, crystalline, massive, dark blue,	42.0′
Limestone, massive, bluish gray, sometimes conchoidal fracture,	20.0′
Limestone, massive, brownish gray, and blue, with alternate layers of gray shaly limestone,	20.0′
Limestone, massive, gray, crystalline and clay limestone, dark blue, with occasional beds of shaly, light gray and lime shales; very fossiliferious,†	50.0′
Limestone beds, partly concealed; mostly thinly laminated clay limestones, blue and gray,	150.0′
Clay limestones, more massive, thinly laminated, bluish gray. conchoidal fracture,	110.0′
Limestone, massive, dark gray and bluish gray, surfaces slickensided and coated with coaly matter; well marked cleavage; contains calcite; lower layers show impressions of fucoids with bivalve shells,	30.0′
Limestone, massive, partly concealed with lime shale alternations,	90.0′

*The list of species will be in the Chapter on Formation No. VII.

†The list of species will be given in the Chapter on Formation No. VI.

Limestone, massive (partly concealed), bluish gray, alternating with slaty clay limestone beds and green and yellow lime shales,	50.0′
Lime shales (partly concealed), yellow and gray,	60.0′
Clay limestone and shale, gray and bluish-gray, slaty,	20.0′
Clay limestone, thinly laminated, blue and yellow, alternating with gray lime shales,	20,0′
Slaty limestone, brownish gray and gray, with calcite seams,	30.0′
Slaty limestone, bluish-gray with lime shales,	20.0′
Clay lime shales, yellow, brown, gray and olive,	20.0′
Mostly lime shales, olive and gray (partly concealed),	50.0′
Shaly limestone, gray, alternating with lime shales, olive,	100.0′
(Partly concealed) mostly lime shale, yellow and green with red shale alternations,	70.0′
(Partly concealed) mostly clay shale, green, yellow and gray with red shale alternations,	150.0′
Lime shales, olive and gray with a few red shale alternations,	50.0′
BLOOMSBURG red shale, sandy (with irregular deposits of green shale), more sandy and massive toward the top where it shows a rhombic fracture,	120.0′
(Partly concealed) mostly red clay shale, with alternations of limeshale, olive and gray,	100.0′
Red shaly sandstone, becoming clay shale towards the bottom; irregular seams of calcite,	50.0′
Olive gray and yellow lime shales with layers of blue fossiliferous limestone,	30.0′
Olive and brownish clay shale and lime shale with layers of blue fossiliferous limestone,	80.0′
Olive and brownish clay shales and lime shales with more layers of limestone towards the bottom,	40.0′
Clay limestone beds, blue and gray, alternating with dark olive shales; lower part clay lime shales, light yellow (very fossiliferous; same fossils with the three last, see F, 248),*	12.0′
FOSSIL iron ore bed, . 10″	
Red sandstone and white shale, . 12″	3.0′
FOSSIL iron ore bed, . 14′	
ORE SANDSTONE; upper part massive, yellow at Rockhill; but very calcareous at Saltillo; middle part an alternation of fossiliferous sandstone (crinoid stems, yellow and green) with shale; lower part more massive,	50.0′
Clay shale green, yellow and gray, (weathering to olive and claret color); near the bottom the surface of the shales are stained with iron and bituminous matter,	600.0′
Clay shales like the last; lower part contains soft olive shales showing impressions of crinoid stems at Three Springs, and red shale partings (containing by analysis 4.29 per cent. metallic iron) at Rockhill,	60.0′

These beds lie on the Medina sandstone No. IV.

* *Atrypa reticularis, Beyrichia lata, Buthotrephis gracilis, Dalmania limulurus, Homalonotus delphinocephalus, Orthis elegantula, Platyostoma niagarensis, Pterinia emacerata, Rhinchonella neglecta, Strophomena rhomboidalis.*

Composition of the Logan, Mt. Union and Orbisonia sections.

Comparing these three sections, we see at the bottom the fixed horizon of White Medina sandstone No. IV, too well marked to permit of a suspicion of mistake, and about 700′ above it the unmistakably continuous *Ore sandstone*, thickening from 38′ at Logan, and 42′ at Mt. Union, to 53′ at Orbisonia. The interval is 756′ at Logan, 668′ at Mt. Union, 710′ at Orbisonia.

Now there is an *Iron sandstone* at Logan, 7′ thick, lying 571′ above Vo. IV; and there is an *iron sandstone* at Mt. Union, 3′ thick, lying only 307′ above No. IV; and at Orbisonia, there is no *iron sandstone* at all. It is quite evident therefore that there is no persistent *Iron sandstone* horizon in this district; and that the Logan and Mt. Union beds are not at all the same bed; have nothing to do with each other; are in fact like most of the *fossil ore beds* isolated local deposits occurring at various heights in the Clinton formation, and deposited at different times in different places. In the Lower Juniata region we have already seen (p. 757) that in the Roundsley's Millerstown section there are two *Iron sandstones* separated by 300′ of shales, and each one with an ore bed. So here the Logan Iron sandstone lies virtually 264′ higher in the series than the Mt. Union Iron sandstone.* It may be that the Logan Iron sandstone is the equivalent of the Danville bed; and the Mt. Union Iron sandstone is the equivalent of the lower Millerstown bed.†

The Ore Sandstone a fixed horizon.

Losing in this manner the *Iron sandstone* as a horizon, there only remains to us the fixed horizon of the *Ore sandstone;* for above this we have absolutely nothing that can be called a fixed horizon, until we reach the *Oriskany sand-*

*Measuring downward from the Ore sandstone the distances are 361′ and 185; the difference in horizon being only 176′, which is quite sufficient however to show that it is not the same iron sandstone in the two places.

†The Iron sandstone in which Prof. Claypole found the oldest fish remains lies 350 beneath the Salina red shale in Perry county, which there in one section rests directly upon the Ore sandstone.

stone No. VII. The Upper Clinton shales, the Salina Red, Variegated and Gray shales, and even the Lewistown limestone and lime shales of No. VI, are all of them subject to the greatest possible variation in character and in thickness.

From the *Ore sandstone* up to the *Oriskany* we have a total thickness, at Logan of 2693′; at Mount Union, 2013′; and at Orbisona, 1614′. There is therefore, a progressive thinning of the interval (southwestward) of nearly 700′ in the first 20 miles, and an additional 600′ in the next 15 miles. So great a failure of material brought in to the water area in so short a distance is one of the remarkable and instructive phenomena of our Pennsylvania geology. It is common however throughout the Appalachian belt of the Atlantic states; and, as we will see in the description of the oil and coal measures, common to the entire region of the United States.

Little remains to be said about the middle Juniata district except to note the following particulars (see Preface to F, xxiii, etc.):

The Water Lime.

The Water Lime formation cannot be distinguished from the upper part of the Salina formation. For nearly 500′ below the massive *Lewistown limestone* beds of No. VI, the deposits are largely composed of hydraulic beds, some of which should make a good cement; others are of a purer quality of limestone; but no sufficient series of analyses have been made of them. At the top, just under the *Lewistown limestone*, there is a massive bed of buff-colored clay limestone with smooth fracture, laminated in very thin and regular layers, some of them sandy. Near the bottom of the group are some massive beds of excellent blue limestone, parted by bastard limestones and lime shales, with soft sandy and limy layers imperfectly slacking when burned and apparently hydraulic; and in fact the whole group is probably charged with a percentage of magnesia as well as lime. These observations relate to the neighborhood of Lewistown.

Salina Variegated Shales.

Salina Variegated shales, both argillaceous and calcareous, more than 400′ thick, underlie the above at Logan and Lewistown, and include layers of fragile limy sandstone. The important point is, that the lower part of this group is the more argillaceous; and that impure limestone layers and lime shales increase ascending toward the top; and passing up into the group last described. The soils produced along the outcrops of this part of the formation are the most productive of the district.

The Logan limestone, 3½′ thick, differs in character from the other limestone beds of the Logan section. However noticeable, it may have no stratigraphical importance; showing no fossils; consisting of three layers; the upper and lower ones being of heavy compact dull-blue limestone breaking into square blocks and weathering to a blue gray; between them lying a very hard layer, heavily charged with iron, and breaking with rough semi-crystalline surfaces.

Bloomsburg Red Shale.

The Bloomsburg red shale has been sufficiently described by the sections. The red layers are abundant for more than 400′; less numerous downward for more than 300′; then very abundant downward for nearly 300′; then giving place downward to Clinton lime shales and olive shales on top of the Ore Sandstone. In the *upper red shale* mass are interbedded green and yellow shales. In Ferguson valley, between Lewistown and Mount Union, these red shales are massed in unusual thickness, but with occasional partings of green shale; and near the middle are about 40′ of variegated layers. This is on the foot slope of Jack's mountain. Where this upper red shale mass crops out south of the Lewistown ridges, nearer the river, very little red shale is visible in it, the whole mass being mostly of green and yellow shale.

The Mifflintown limestone is a name given in Juniata county to a group of thin hard calcareous-sand-beds, each only 2″, 3″, or 4″ thick, parted by very thin limy sandstone layers, mottled with red. This little group is only 6′ thick, but is so peculiar in its character and so persistent as a deposit, that it is of considerable local importance to the geologist, who can recognize it in places far apart from each other. It seems however to turn into a sandy limestone, and sometimes into a comparatively pure limestone; as, for example, near Mifflintown in Juniata county, where it crops out on the west bank of the Juniata 3′ or 4′ thick. Great care, however, must be taken, not to identify such beds rashly. All that can be said of this one is, that at the base of the upper mass of red shale, lies a peculiar small group of sandy limestone at Mifflintown and elsewhere.

Upper lime shales.

The 300′ of strata underlying the upper red shale are sufficiently characterized by their general color, from greenish gray to green and yellow (with an occasional reddish layer) weathering to a dark olive, to be readily followed along a broad outcrop by the field worker, whatever name he may give them. They are called in Report F *the Upper Lime shales and Gray Variegated shales.* The rock is usually heavy and compact, sometimes quite sandy, generally calcareous, and making superior farming land along the little valleys. In the middle of this group, in Ferguson's valley, is a peculiar set of beds supposed to be the same as those outcropping at Lost Creek in Juniata county.

The Lost Creek limestones.

The Lost Creek limestone group, 60′ thick, contains several light-blue shaly limestone beds, one sandy limestone bed at the bottom; some of them very massive; single beds having a solid thickness of 6′ or even 8′; parted from each other by gray shales. In Lost creek valley, Juniata county, a few quarries have been opened on these beds because the *Lewistown limestone* beds are not there available. The same group of beds are recognizable near Mifflintown.

Lower red shale.

The lower red shale is perhaps the real representative of the *Bloomsburg red shale* of the Montour country. It is finely exposed in the Juniata river bluffs above and below Mifflintown, mainly red shale interbedded with green shales. When the dip in the mountain of No. IV is gentle the red outcrop of this group creeps up the foot slope and makes it tillable. Near the middle of these red shales lies a peculiar local deposit, named from its bold outcrop at McCoytown, Tuscarora valley, Juniata county.

McCoytown sandstone.

The McCoytown sandstone is a group of soft sandstone layers, each from 6″ to 24″ thick, breaking into square blocks; but near McCoytown these soft sandstones become very hard and flinty, and have their surfaces covered with quartz crystals.

Lower Lime shales.

The Lower Lime shales are described by Mr. Dewees as varying from 30′ to 160′; shaly in the upper part; growing more calcareous downward; the harder layers (1″ to 12″) separated by softer shales being locally burned to lime.

Upper Olive shale.

The Upper Olive shale (called by Mr. Dewees *Upper fossil-ore shale*), varying from 30′ to 150′ and in the Logan section 250′, is a series of blue-gray, sometimes buff-colored, somewhat limy, tough shale; the lowest bed of the group (just over the Sand ore bed) being often changed into a white soapy shale (called *soapstone* by the miners) by the drainage water; as may be seen best in Lost Creek Ridge north of Mifflintown and along the ridge eastward; the dip of the strata here coinciding very nearly with the slope of the surface.

Soapstone shale.

In this soapstone shale we have an instance of how the operations of nature instruct the miner to find his mineral, and to estimate its value even before he finds it. The shale is the roof of the *Sand-Vein Fossil-ore bed.* The rain-water, percolating through these two beds, changes and softens the shale into a soapstone, and the hard limestone into soft iron ore. Therefore, if a miner finds the roof shale in the state of a greasy clay he knows beforehand that he will find soft fossil ore; but if his trial-pit goes down through hard bluish-gray shale, he is sure beforehand that he will find beneath it the unchanged hard lean fossiliferous limestone, with little or no soft ore. The change takes place at various distances beneath the surface according to the facilities afforded for the percolation of the waters. The shales which outcrop at or under water level are always hard, olive colored, and without a trace of soapstone; and the ore-bed also is hard. Sometimes the shales over the ore-bed are themselves highly charged with iron and then the ore-bed itself is found of extra thickness. At Shade Gap a shaft was sunk through 50′ of buff-colored shales.

Fossiliferous limestone beds from 1″ to 12″ thick are scattered through this mass of shales, especially in its lower part, next over the Ore sandstone group; and if conditions had favored the concentration of iron in them, they would all have become local ore beds. As it is, in various parts of the region, here one and there another of these local beds of fossil limestone has been turned into a *local fossil ore bed.*

Fossil Ore Sandstone group.

The Fossil Ore Sandstone group is composed at the top, of the Sand Vein Ore bed; in the middle, of the Sandrock 3′ or 4′ thick; and at the bottom of the main mass, of Ore sandstone about 25′ thick, making a ridge or terrace on the flank of the mountain, guiding the miners to the ore.

The Sand Vein Ore bed is sometimes merely a fossiliferous limestone and sometimes a rich red hematite fossil ore bed. Sometimes its sandrock floor is sufficiently rich in iron to be mined, but the mixture makes a cold-short pig iron. When the floor sandstone is thus an ore it is very fine grained, that is, it lacks the coarse quartz sand grains which characterize the rock elsewhere. On Licking creek near Mifflintown where the ore bed is soft and rich the rock floor is also a soft ore. Where the ore bed is hard, that is, an unchanged limestone, its floor is a hard sandrock. Sometimes the ore bed lies on a layer of disintegrated or loose sand, which in mining gets mixed with the soft ore and makes the pig metal cold short. Sometimes in the middle of the ore bed, and at other times at the bottom of the ore bed, occurs a layer of lean clay-ore from 2″ to 8″ thick, thickest usually when the ore bed is thickest and *vice versa*. The miners call it "*Jack*" and it is usually rich enough in iron to be sent with the better ore to the furnace. The ore, thus either pure or mixed with *Jack*, varies in quality from 20 to 45 per cent of iron. It may still be enriching itself by percolation. There are many thin fossiliferous limestone layers in the shales above the ore bed which have never been changed into ore beds themselves. The concentration of iron in the group seems to have taken place wholly on top of the sandrock and between its grains of sand. But this view is rendered doubtful by the fact that the ore bed is in some places cut out by a horse of shale, which is nothing but the rolling down of the roof to the sandrock floor, in which cases the upper layer of the sandrock floor is the only ore mined.

Another rule has been established by the miners, but like all miners' rules it is subject to many exceptions. This rule is that the ore bed is generally thickest where it is covered with the greatest thickness of shales; and when the overlying shales are less than say 20′ the ore bed does not exist or is at least very thin. A similar rule was established by the First Survey in its study of the Buhrstone brown hematite ore of the coal measures in western Pennsylvania, and gave occasion for adopting the theory that the iron had been leached from the overlying shales downward upon the Ferriferous Limestone, which being dissolved away its place was occupied by the iron ore. In all essential particulars this theory has been proved true in most of the mining regions of the world; and it may therefore be safely applied to the fossil ore bed under consideration.

The ore is softened to different depths from the outcrop, down the slope of its dip, the distance being limited by the depth to which the drainage water can descend before finding an outlet sideways. Gangways starting from water level in deep ravines have been frequently driven under neighboring shallower ravines, still in soft ore; but the plane of underground drainage level and consequent limit of soft ore rises and falls; and as a general rule the limit of soft ore going down is more quickly reached on a divide between two ravines than in the ravines themselves.

It must not be taken for granted that because the ore bed is hard and unchanged at a given point at the outcrop there exists no soft ore underground; for the drainage sometimes undercuts unchanged part of the bed, finding its way diagonally downwards through broken, slipped, or faulted zones of the bed, changing it to soft ore sometimes to a considerable depth.

In some places the ore bed has a rider layer of ore separated from the main bed by a thin stratum of shale or sandstone; and this fact will help to explain the layer of *Jack* in the body of the bed.

Ore sandrock.

The Ore sandrock, the floor of the ore bed, is in some places 4′ thick; in other places thinning away to nothing; and then there is no ore bed over it or merely a trace of ore. It is often a layer of coarse rounded sand grains, either entirely loose sand or sand loosely cemented with per-oxide of iron. In some places it is a smooth layer of compact fine grained clay sandstone. In other places its lower layers are more like a lime shale than a sandstone; and then these lower layers by the solution of the lime make an excellent water way, which again has the effect of thoroughly softening the ore bed. The line of outcrop of the sandrock is very deceptive to the eye, being often a belt of surface fragments looking like rich ore, but in fact perfectly worthless as ore, but of the highest value as a guide to the miner seeking the outcrop of the overlying ore bed. The line of outcrop is however often interrupted by the entire disappearance of such fragments from the surface, the sandrock itself having thinned down to 2′ or 3′ of loose sand; the ore also being absent; and the overlying shales resting directly on the ore sandstone next to be described Where the sandrock is thick it is full of impressions or casts of shells which have been dissolved and removed. This has also produced a quantity of plastic clay, layers of which separate the layers of sandrock. Sometimes the shells are so abundant as to make the sandrock nothing but a hard compact fossiliferous limestone, unchanged, with its shells remaining undissolved, and supporting the ore bed also in a condition of unchanged hard fossiliferous limestone.

In Ferguson valley under the Sandrock and over the Ore sandstone next to be described lies an unimportant thin soft porous rich fossil ore bed only from 2″ to 4″ thick, showing by analysis 50 per cent of iron.

The Ore sandstone makes a prominent terrace and often a distinct little ridge where it runs along the slope of the mountain; the outcrop of the Sand vein ore bed being just below and in front of it, and the outcrop of the Danville ore beds just above and behind it. This happens when the dip is gentle or when there is a little synclinal roll. The Ore sandstone ridge is always very strongly marked where it sweeps around the declining ends of the anticlinal mountains of No. IV. Of course it is bolder where the sandstone is thick and massive; where it is thin there is hardly a ridge at all, but merely a low terrace strewn with fragments broken from the few thicker layers, and mixed with *dèbris* from the underlying shales and limestone outcrops higher up the slope. It varies in thickness from 8′ to 10′ in Mohontongo gap on the south side of East Shade mountain near Tremont in Snyder county, to 35′ on the south side of the Perryville ridge in Juniata county; but this is only its main mass or the Ore sandstone proper. There must be added underlying layers of laminated friable clay sandstone, separated by shale partings, overlying the Danville ore beds; and this lower division varies from 10′ to 25′. In Klopperdale valley south of East Shade mountain the Ore sandstone proper is only 8′ thick; the overlying ore bed being hard and lean and traversed by vertical cleavage joints, letting the drainage waters through the sandstone down upon the Danville ore beds, altering them to soft ore.

The top layer of the Ore sandstone is in some places charged with iron; in other places the whole deposit is a whitish massive sandstone, breaking with a square fracture and full of fossils; elsewhere it is in layers very fragile and much broken, a character which prevails at the east end of Jacks mountain around Centreville in Union county and also on the eastern side of the Susquehanna. Here a bed of shale 5′ to 7′ thick occurs in the middle of the formation, with greenish sandstone beds above and below, the whole amounting to say 20′. The upper greenish sandstone member is more fragile and broken than the lower one, and has absorbed a notable percentage of iron by percolation from the overlying shales.

This Ore sandstone formation is of great importance, not only on account of often carrying the Sand Vein ore bed; but because, when it is close grained, massive, compact, and therefore not permitting the drainage waters to go through it, the underlying Danville ore beds remain hard and lean, and of little value, even near their outcrops; whereas when it is thin, and traversed by cracks through which the drainage waters can descend to the Danville ore beds, these latter are soft and rich, even to a great depth beneath the outcrop.*

*Figured sections of the Ore Sandstone and the overlying and underlying strata may be found on pages 50, 57, 58, 74, 102, 108, 118, 130, 132, 247 of Report F, the texts of which are as follows:—

In the Juniata Narrows S. of Lewistown:—U. C. fossil ore shales, with traces of sand vein ore, 50′; Ore sandstone, argillaceous, alternating with small beds of silicious shale, 10′; Ore sandstone, massive, cleavage planes 6″ to 1′ apart, 12′; Siliceous shale, 24′; Danville ore bed rock with traces of the ore, 10′; M. C. shales, with many thin limestone beds, 36′.

At Granville gap in Shade Mountain, Mifflin county:—Ore sandstone, argillaceous layers, on top of Ore sandstone, siliceous, massive, with cleavage planes 6″ to 1′ apart, 12′; sandy slates and clay sandstone beds alternating, 30′; Danville ore group very argillaceous, 15′; on Lower Clinton shales.

McKee's ore bank:—Sand vein ore bed, 12″ to 18″; mottled purple and white rock several inches thick at the top of the Ore sand rock, fragile, coarse and ferruginous, 3′; Ore sandstone, massive, 15′ to 20′

At J. Shehan's ore bank, west of McKee's ore bank:—Sand vein ore bed, impure and shaly at bottom, 16″: Sand rock, 2′ to 3′; Spongy ore, containing small fossil shells, at the top of the Ore sandstone, 18′.

At McVeytown:—Upper Clinton fossil ore shales, 54′; clay sandstone 10′, and sandstone 15′, together representing the Ore sandstone; Siliceous shale, 24′; Danville ore group, 12′; Clinton shale.

At Matilda furnace:—Fossil ore shale; Sand vein ore bed; Ore sandstone and sandrock, 25′; siliceous shale, 13′; clay shale, 2′; fossil ore bed 3″ to

The Danville fossil ore bed group.

The Danville Fossil Ore beds underlie the lower or shaly division of the Ore Sandstone group, described above as alternate laminated clay sandstones and shale beds, 15′ to 20′ thick. The group consists of three or four beds of fossil ore in a vertical distance varying from 6′ at Berlin in Union county to 15′ at Mount Union in Huntingdon county. The beds at Mount Union are larger than at Berlin. The rock layers between the ore beds are generally fossiliferous clay limestone; at some places sandy friable porous and honeycombed, that is, full of cavities from which the fossil shells been dissolved away; in which case the ore beds proper have yielded soft ore; where the intervening layers are solid the ore beds are also hard and lean. The intervening strata have but very little iron where the ore beds are hard; but where the ore is soft the intervening layers seem to have absorbed more or less iron, sometimes enough to make them valuable for furnace use. Here and there white silicious clay has been liberated, containing small quantities of kidney or liver ore, as in Klopperdale valley, Snyder county. In the Perrysville ridge, Juniata county, they are solid rock layers,

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4″; fossiliferous limy rock, 3″; Upper Danville ore bed, a fossiliferous limestone, 18″; fossiliferous limy rock, 4′; Danville ore bed, 10″; fossiliferous limy rock, 5′; Lower Danville ore bed, 8″ to 10″; clay shales.

At Orbisonia, Mine No. 1:—Upper Clinton green fossil ore shale; hard Fossil ore bed 3″ shale, 8″; fossil ore bed, 3″; fragile sandstone, 20″; fossil ore bed 16″; Ore sand rock.

At Orbisonia, Mine No. 2:—Fossil ore shale, light colored; hard Fossil ore 8′ to 10″; friable ferruginous sandstone 1′; Sand vein ore bed, 18″; Ore sand rock, 2′ to 3′.

At Orbisonia, Mine No. 3:—Upper Clinton fossil ore shale; soft yellow green shale, 4′; light green shale, 14″; sandy ferruginous shale, 12″; soft clay shale, 5″; fossil ore, 8″ to 10″; Sandstone ferruginous fragile, 10″; Sand vein ore bed, 22″; Ore sand rock 2′ to 3; Ore sandstone.

In the Black Log Section this is continued downward thus:—Ore sand rock, 35′; Olive shale, 5′; Danville ore bed, thin; Olive shale, 11′; Danville ore bed, thin; Lower Clinton olive and gray shale, 660′.

In Ashburner's general section, F, 248, the Fossil ore group is represented thus:—Upper fossil ore bed, 10″; red sandstone and white shale, 12″; Lower fosail ore bed, 14″; safe averages; Ore sandstone, upper part composed of massive yellow sandstone under Rockhill ore bed (at Saltillo, upper part very limy); central part, yellow and green fossiliferous sandstone (crinoid stems) alternating with shales; lower part much more massive.

and the group of ore beds is represented merely by some thin layers of fossiliferous limestone; below which, at various distances in the great underlying shale formation, occur numerous smaller fossiliferous limestone layers from one to ten inches thick, alternating with lime shales. Here one of these lower limestone layers (the Lauber bed) is a sufficiently good ore to work. The Danville Ore beds run commonly from 4″ to 8″ thick, and are often near enough to allow two and sometimes three of them to be worked in one gangway; as at points east of New Berlin in Union county, where the soft fossil ore is mined on the side of Jack's mouetain. Where the ore beds are separated too widely to be mined together one of them will sometimes be as much as 3′ thick, the others remaining small; and this also happens in Union county.

The Clinton Middle olive shales.

The Clinton Middle olive shales occupy the whole space between the Ore Sandrock above and the Iron Sandstone below, whether the Iron sandstone be one horizon or more as already described. In the Logan section there are 178′ of shales under the Ore sandstone without any exhibition of the Danville ore beds; their general color being olive green, gradually changing to a prevailing purple mixed with dark green. The upper part of the mass is seldom free from beds of fossiliferous limestone; and these at various localities are so numerous and lie so close together as to constitute an almost solid mass of limestone strata with lime shale partings. In other localities beds ofsandstone abound near the bottom of the mass. Of the fossiliferous limestone layers just mentioned one or another will be locally converted into a fossil ore bed; and this is the explanation of the Lauber fossil ore bed in Lost Creek ridge north of Mifflintown, Juniata county, mentioned above. The Danville group of ore beds may in fact be considered as special instances of these limestones near the top of the mass, and they are as frequently absent from it as present. In fact it will be seen from all that has been said in this description, that *there is in reality no fixed fossil ore horizon*, but that hundreds of fossiliferous limestone layers were deposited in the Clinton age, here and there, over a perpetually growing sea bottom, some of which were afterwarbs converted into ore beds in one place and others in another. The extremely local character of the change of a limestone layer into fossil ore is illustrated by the innumerable instances where fragments of ore are found on the ground along short ilnes which when followed down for mining lead to no practical results and prove to have no mining value whatever. The larger beds of limestone show most iron near the outcrop; but when followed underground the charge of iron vanishes. A limestone bed for example on the crest of Lost creek ridge was opened by Mr. Hirsh but soon lost its iron when the cover became heavy. In a word, these limestones will always exhibit the aspect of ore near the surface where the cover is light and the percolating waters have acted on them; but not underground.

The Iron Sandstone group.

The Iron Sandstone group in the Logan section is about 7′ thick, subdivided into two layers by an intermediate shale 3′ or 4′ thick, leaving only one foot of the sandstone at the bottom. In some parts of this region more than 50′ of alternations of iron sandrock and shale appear in a single outcrop. As an iron ore it is of little value, but occasionally one or other of its layers will be somewhat softer and better than the rest. The Iron sandstone outcrop runs on the ridge north of Shade mountain from Adamsburg to Paxtonville with extremely variable size and quality of ore.

The Clinton Lower Olive shales.

The Clinton Lower olive shale mass in the Logan section measuring 560′ is as a whole more silicious than the shale mass above it. It contains many thin beds of sandstone and very few layers of fossiliferous limestone; but at the bottom are yellowish green iron stained laminated clay slates exhibiting numerous fossil impressions and crumbling readily under the action of the weather. The uppermost layers of the whole group weather to a dark green color. In fact the Iron sandstone may be taken as the lower limit of the real calcareous strata of the Clinton formation; true limestone strata which are so common in the column of rocks above it being scarcely ever seen in the column of rocks below it.

A group of somewhat sandy shales varying in color, purple and different shades of green in alternate beds from 2′ to 12′ thick, with thin layers of steel gray sandstone, lie in the mass of Clinton Lower shales from 100′ to 150′ below the Iron Sandstone.

Still lower are harder olive green shales alternating with purple shales; and at this horizon (150′ to 200′ above the top of IV) occurs the Bird's Eye fossil ore at Paxtonville on the north slope of East Shade mountain in Snyder county.

In the Clinton Lower olive shale mass in Snyder county, both north and south of East Shade mountain, three beds of Block ore may be traced in outcrop and are mined separately at various places; the *Boyer block ore* say 200′ beneath the Iron sandstone; the *Bird's Eye fossil ore* say 100′ beneath the Boyer; and the *Shot block ore* say 100′ above the top of No. IV.

The Boyer block ore where opened in Mahontongo gap northeast of Tremont is 6′ thick and part of it yields good ore.

The Bird's Eye fossil ore bed.

The Bird's Eye fossil ore bed at the Paxtonville mines is about 10″ thick on a gentle dip with a regular floor and a rolling roof; the rolls occur every few yards in the mine making the bed vary between 6″ and 14″. Purple shales underlie this ore bed for 10′ to 25′. The ore comes out in trapezoidal blocks 15″ to 18″ long and of the thickness of the bed; the vertical seams pass diagonally through the bed leaning from 25° to 30° from the vertical; and these seams have assisted in softening the ore. The same bed is mined east of Paxtonville at Middleburg, Smith Grove and Freeburg; and also at Welker's on the Tremont road south of Shade mountain in Snyder county; also about 5 miles from Selinsgrove on the Susquehanna river. Mr. Dewees reports that a larger price is paid for this than for any other fossil ore (F, p. 47).

The Block ore bed.

The Shot Block ore bed is so called from its containing minute clay pebbles the size of shot. It varies from 6″ to 8″ thick and is worked in the vicinity of Beavertown in Snyder county where the other beds are also worked; also to some extent on Lost creek ridge. It is exposed in the Paxtonville quarries with a bed of compact silicious clay breaking with a shaly fracture and smooth surface and easily cut with a knife.

The whole Block ore series thus described is exhibited in the Paxtonville section (F, 21) and in the Smith Grove section (F, 46).

Fossil ore on the east slope of Shade mountain.

The Rock hill mines at Orbisonia in southern Huntingdon Co. have been driven along the beds south of Black Log creek, meeting a succession of cross faults, inclined at 30° to the north, giving throws of from 1′ to 30′ in the gangways, always to the west, north of each fault. To obtain more ore the company has built a railway through the Black Log and Shade gaps to reach the east dipping beds on the eastern slope of Shade mountain. At the Shade gap the bed was only 4″ thick and continued so for 1500′. Here the Cornelius tunnel was driven 500′ and found the upper ply of the bed 6″ thick. Further on the Piper tunnel was driven 795′ to the bed which was exhausted. Still further on, the Shearer tunnel was driven in 800′ to the bed. The next (Stair) tunnel is 13,000′ to 14,000′ from Shade gap, and was driven in 868′ to the bed. Here the main bed varied from 3″ to 12″ on a dip of 20°. For the next 6800′ prospecting along the outcrop discouraged tunneling. Then the bed became 9″ thick, on a dip of 52°, and continued good (as explored) for 16,500′ to the Goshen tunnel, 1028′ long, where the bed is 27″ thick, analysing 47 per cent. of iron. About 6000′ further the Nancy tunnel was driven 1500′ in to the bed and here the track ends. From the two tunnels, the Goshen and the Nancy, the output is 300 tons a week. A mile and a half further the Rochvale tunnel has been driven in 800′ to 900′ to the bed, and the extension of the road has been graded but not yet laid. No doubt the east slope of Shade will be mined further on northwards.

Southward from Shade gap the ore bed has been found unworkable for two miles; but workable from that point on south toward Fort Littleton in Fulton county.

The dip along the Black Log outcrop is very regularly 75° westward. That of Shade mountain about 50° eastward. But there is always a creep of the mountain slope which reverses the dip for a distance down from the surface. Cross faults are encountered in the Shade mountain mines precisely similar to those in the Black Log mountain mines, the hade of each fault being low to the north, and the gangways being curved always in the same direction to recover the lost bed. The bed is double and the upper ply has the best quality but not always the greatest thickness.

On the southeast side of the Tuscarora valley, along Tuscarora mountain, northeast and southwest of Burnt Cabins on the Huntingdon and Fulton county line, the outcrop ore has been disappointing. But further northeast, in the Nossville district, fine outcrop shows have been obtained, and future iron mining on a 2½′ and 3′ bed is sure to be profitable. This approaches Juniata county, where profitable mining operations will be established on the outcrop when railway facilities shall have been offered.

Chapter LIX.

No. V in the Huntingdon valley.

By the Huntingdon valley is not meant merely the cultivated low land northeast and southwest of the Juniata river at Huntingdon, lying between Warrior's ridge on the northwest and Little ridge on the southeast, but that much more extensive country northeast of the Juniata and Little Juniata, enclosed between Tussey mountain on the northwest and Standing Stone on the southeast, and shut in by the Seven mountains of Centre county at the northeastern end; sub-divided by Warrior's ridge and Little ridge into three subordinate valleys, the largest of which is called Stone valley and Shaver's creek valley in front of Tussey mountain; the middle one the Huntingdon valley proper, watered by Standing Stone creek, Morris run and Grove run; and the Mill creek valley lying at the foot of Standing Stone mountain.

This great Huntingdon valley is extended southward between Tussey mountain and Terrace mountain, through Huntingdon and Bedford counties into Maryland, and is traversed lengthwise for 40 miles by the Raystown branch of the Juniata.

Formation No. V outcropping in the Juniata valley described in the last chapter, follows the eastern slope of Jack's mountain, turns its southern end at Scottville and Saltillo and runs back north through Hare's valley to Mapleton (8 miles below Huntingdon) where it re-crosses the Juniata and follows the west slope of Stone mountain northward 20 miles to Greenwood furnace. Here it spreads out over the numerous anticlinal and synclinal rolls of the Seven Mountains; sweeps around the north end of Warrior's ridge; returns by Tussey mountain to the Juniata at Petersburg and Alexandria; crosses the Little Juniata and keeps on south as Hartzlog valley and Woodcock valley along the slope and foot of Tussey mountain 40 miles to Everett (Bloody run); crosses here the Raystown branch and continues to follow Tussey mountain 20 miles further to the Maryland line. The whole formation is exhibited in the gaps of the Juniata and its two principal branches and Yellow creek; and its fossil ore beds are mined at Greenwood furnace extensively (as described in detail by Mr. Billin in Report T3, page 237), Jackson township, Huntingdon county. The extraordinary loops of the outcrop of the fossil ore in this district is exhibited on page plates T3, 232 and 236, reproduced here on Pl. XCIII and CI, with cross sections on Pl. C. The ore beds are mined frequently and extensively along the foot of Tussey mountain south of Alexandria, McConnellstown and Marklesburg; and very extensively in the vicinity of Everett, 8 miles east of Bedford, in Bedford county.

The Huntingdon Valley.

The great Huntingdon valley represents the widest and deepest synclinal trough which traverses the state and holds in eastern Pennsylvania the great Northern Anthracite Coal Field and in middle Pennsylvania the curious isolated Broad Top Coal Field. The southeastern wall is made by the vertical rocks of Standing Stone and Jack's mountain; and the northwestern wall by the much more gentle southeast dipping (30° to 45°) rocks of Tussey mountain. Along the whole line of Hare's valley and its continuation as Mill creek valley, that is, from Saltillo to Greenwood furnace, a distance of 35 miles, formation No. V stands nearly vertical and no mining of fossil ore has ever proved successful. On Mill creek the formation is pinched apparently by a crush fault, such as we may always expect to find accompanying the vertical or overturned northward dips of a great anticlinal; the great anticlinal in this case being that of Jack's mountain and Kishicoquillis valley.

The principal features of Formation No. V in this region are 1. well recognizable Upper, Middle and Lower Salina groups, in all about 1125′ thick; 2. Upper, Middle and

Lower Clinton shales, in all about 1350′ thick;* 3. a well defined *Ore Sandstone* group about 600′ above the top of No. IV; 4. a horizon of Block Ore 400′ above No. IV; and 5. a remarkable group of *Barre Limestone* beds near the top of the Clinton, which may possibly be the representative of the Niagara Limestone Formation, yielding as it does a coral-like fossil resembling the characteristic New York Niagara species *Favosites niagarensis*.†

A short description will be given of this series commencing at the top.

The Salina Upper buff-colored magnesian limestone beds measure from 375′ to 455′ in the different sections along Tussey mountain. They represent 330′ of similar beds in the Montour ridge gaps in Columbia county. If the gypsum and salt of New York existed in Pennsylvania they would be found in this group. The top of the group, that is the top of the Salina Formation, can here be clearly separated from the overlying Lower Helderberg formation No. VI, first by the buff color of the top beds and by their magnesian character; and they are distinguished from the Middle Salina mass by the absence of green shales and shaly limestones. The Upper Salina beds however, are everywhere poorly exposed, making the foot slope of Warrior's ridge and a part of the Little Valley bed beneath it.‡

*T2, 131. I have removed the shales with ore 75′ and the red shales 50′, from the Clinton and included them in the Salina.

†There is some mistake in report T3 about the Lower Clinton shales. The constantly assumed thickness of 400′ beneath the Iron sandstone is merely an inference from one exposure above Barre forge (T3, 131, 140, 222 section). Here block ore fragments lie on the surface, but the Iron sandstone block ore bed is not seen; and therefore the block ore fragments, calculated to lie 405′ + No. IV, can have nothing to do with the block ore horizon which in Bedford county to the south is doubtfully 10′ and in Blair county to the northwest doubtfully 100′ above No. IV.

‡Galena lead ore in small pieces is often found near the contact of the Upper Salina shales with the overlying Lewistown limestone. A mile northeast of McConnellstown shafts were sunk and tunnels driven into the lowest hard limestones in Warrior's ridge, but only lumps of lead ore were found enclosed in veins of calcite ramifying through the lime rock, amounting in all to not a ton of lead ore. It is quite safe to predict that neither lead nor zinc will ever be profitably mined from this horizon in this district; nor in any other district of this formation in the State of Pennsylvania.

The Salina Middle green shales and slaty limestones measure from 400′ to 500′ and correspond to the 410′ of similar strata in Montour's ridge east of the Susquehanna. There are a sufficient number of hard beds in this group to make a low ridge, which is not conspicuous in Shaver's creek valley north of the Juniata, but becomes so in Hartslog valley, and continues to make a strong mark on the surface, as Mulberry ridge, southward through Woodcock valley and onward through Bedford county into Maryland. The Lower Salina (Bloomsburg) red shales 200′ thick also makes a ridge which is everwhere noticeable. These two ridges running side by side in front of the steep escarpment of Warrior's ridge northeast of the Juniata are merely low swells in the general valley floor say 50′ high; but south of the river they unite in Mulberry ridge and become a continuous hill about 200′ high. This hill however, has not a perfectly regular continuous crest because the crest is produced in some places by an increase of hard limy sandstone beds interstratified with the magnesian green shales, and sometimes by the limestone beds of the middle group. The two groups carry the best farming soil of Hartslog and Woodcock valleys; and where they spread out north of the Juniata they make that part of Shaver's creek valley exceedingly fertile. Some of the limestone layers would make good lime, but most of them are too impure and lime burning has been tried at only one or two places. A bed of *black shale* has been noticed at one place about 700′ down in the Salina series.

Brown hematite iron ore deposits follow the outcrop of the Middle Salina produced by the decomposition of ferriferous limestone beds; and a large deposit of this kind at Everett in Bedford county is described in report T2. Surface lumps of ore from the size of one's fist to the size of a barrel lie scattered along the outcrop in Woodcock valley south of the river, and in Shaver's creek valley north of it. A sample from the outcrop a mile from Marklesburg yielded 44.550 per cent. iron; 18.780 silicious matter; and 0.065 phosphorus. Another sample 58 of iron; 8 of silica, etc.; 0.216 phosphorus. But such blocks along the outcrop of shales are not good practical evidence of deposits of value underground; for as the surface moulders down in the course of ages to lower and lower levels by rain erosion, isolated chunks of ore in the shales not being carried away accumulate along the outcrop and produce a delusive show.

The *Salina Lower* (*Bloomsburg*) *red shale* formation in this district is divisible into 1. a top group of red shales, 75′ or 100′ thick; 2. a Redstone ridge group, say 25′; 3. a group of dark red shales 75′ to 100′; 4. a group of bluish gray and olive shales, containing sometimes a thin *fossil ore* bed 75′; and 5. a group of red shales 50′; in all about 325′, representing the 440′ at Danville and Bloomsburg.

The beds of the second group are hard strata, each 1′ or 2′ thick, and almost sandy enough to be called red sandstones. In some places the single group of 25′ is separated into two groups by 5′ or 6′ of green limy shale. Irregularly seggregated seams of quartz traverse these sandstone beds and indicate the amount of solution of silica which has taken place. These hard beds make Redstone ridge * which for several miles south of McConnellstown is kept a mile away from the foot of Tussey mountain by a gentle east dip, and by several rolls; but the dying out of the rolls and the steepening of the dip going south acting together draw the ridge to the foot of the mountain; so that from Marklesburg southward, and through Bedford county, it forms the lowest terrace on the mountain slope. Just north of Marklesburg a set of sharp wrinkles, repeating the outcrops, produces seven or eight distinct parallel Redstone ridges which unite with each other in zigzags. North of the Juniata along the valley of Shaver's creek the Redstone group is thinner and makes a low but still perceptible ridge.

The Bloomsburg red shale is exposed along Gregory run

* The red color is in the main, confined to this Lower Salina division; but in one or two places a red shale bed has been noticed, lying as much as 250′ or 300′ above the Redstone ridge group. A slaty cleavage is often well developed both in the upper red shales and in the sandstones.

which enters Shaver's creek 6 miles northeast of the Juniata at Petersburg near the Logan-Barre line (T3, 228.)

Gregory run section.

Lime shales and grits making a continuous ridge,		—
Blackish shale, exposed,		2′
Magnesian limestones, impure, greenish,		250′
Lime shales, greenish,		10′
Red shale,	50′	
Hard, red sandy beds,	5′	
Red shale,	5′	
Lime shales, yellowish gray,	10′	100′
Redstone Ridge red sandstones, hard,	15′	
Lime shales,	5′	
Red shales,	10′	

Probably 50′ more of red shales underlie the section, making the total thickness of Bloomsburg red shale 150′.

Fossils in the Bloomsburg red shale are here as everywhere else very rare.

The Bloomsburg red shale has been made in these pages to extend downwards so as to include the bluish gray and olive shales, with the *Saltillo ore bed* (75′) and underlying red shales (50′) which Prof. White in Report T3, p. 131, arranges as the uppermost member of the Clinton formaton. The ore bed is in the middle of the shales, which vary from 75′ to 100′. The lower red shale formation (50′) is persistent in this district, and is also represented in Aughwick valley at Saltillo, etc.

The Saltillo fossil ore bed makes its appearance here and there, in the shales above the Bloomsburg lowest red shales along Tussey mountain. At Orbisonia in southern Huntingdon it does not appear; but at Saltillo at the south end of Jack's mountain it is mined. Here at Saltillo the *Lower Salina* is subdivided thus:—At the top, sandy red shales (with green layers) 120′; then, red clay shales with green and gray lime shales 100′; then, the *Saltillo fossil ore bed* 2′ 4″; under it red shaly sandstone layers′, 50; in all 270′. The ore-bed consists of a top layer of soft ore 8″, and a bottom layer of harder ore 8″, separated by 12″ of yellow lime shale. Careful measurements make this bed lie 210′ above the *Orbisonia* (*Sand Vein*) *ore bed.* Along Tussey mountain it lies about 300′ above the Ore sandstone.

At R. W. Given's in Walker township are seen: blue shaly magnesian limestones 20′; red shales 30′; hard red sandstone of Redstone ridge 7′; red shale 5′; lime shales and concealed strata 100′; upper (Saltillo) fossil ore bed, 162′. This shows that the *Saltillo ore bed* along Tussey mountain underlies the Redstone ridge hard red beds at the bottom of the Salina about 100′. This ore bed (here 8″ to 10″) was once supposed to be the regular (Danville) ore bed of the district underlying the Ore Sandstone, although no sandstone was to be found on top of it. The two beds are in fact 300′ apart, but are of exactly the same character, filled with minute fossil shells, the same species in both. About 20′ under the upper ore bed occurs a thin fossiliferous limestone (T3, 207).

The *Clinton Formation* has been described by Professor White in the Huntingdon valley in general terms thus:

Clinton Upper	Olive shales,	60′	1332′
	Barree limestone group (Niagara?),	175′	
	Olive shales,	60′	
Ore sandstone,		10′	
Danville fossil ore,		1′–2′	
Clinton Middle olive and reddish shales and hard flags,		600′	
Iron sandstone and block ore,		25′	
Clinton Lower olive and reddish sandy shales,		400′	

The Barree Upper shales might be included with the red shales and olive shales above them in the Lower Salina with as much propriety as the red and olive shales were in Report T3 (p. 131) included in the Clinton. There is no canon of classification applicable to this excessively variable formation No. V, as has been repeatedly said already. If the Barree limestone group could be proved to represent the Niagara Formation of New York, then *all* above it should receive the name Salina and all below it the name Clinton.

The Barree limestone group varies extremely in character. It generally consists of a mass of shales 175′ thick with pure limestone layers near the bottom; but in some localities these pure limestone layers thicken up greatly; and at Barree Forge on the Little Juniata, amount to nearly

150′ of the whole. Very thin beds of light gray, bluish gray limestone, streaked with calcite, slightly fossilferous, separated by greenish gray shales are quarried for furnace flux. Three analyses of the limestone gave 96, 91 and 90 per cent carbonate of lime.† The third analysis showed 2 per cent carbonate of magnesia, 1.79 oxide of iron and alumina, 5.66 silicious matter, and 0.014 phosphorus. Traces of phosphorus were also found in the first and second analyses. The first and second analyses showed 0.750 and 0.190 per cent sulphur.

The group of limestones are exhibited in a cut on the Pennsylvania railroad 100 rods east of Barree station, as a series of thin bedded, blue and bluish gray limestones, interstratified with gray shales, slightly fossiliferous, 150′; under which appear bluish gray shales, fossiliferous, with occasional limestone beds, 75′; lying on the Ore sandstone. The *Favosites* are to be found near the top of the limestone group, in masses about the size of one's fist, standing out from the surface because resisting the weather. In the limestone beds are numerous shells apparently broken up by the waves or perhaps drifted from a distance. The limestone layers in the *Barree Lower shales* (75) are almost entirely confined to the upper half, and a small *Brachiopod* shell is very numerous in the limestones and in the upper shales; while near the bottom are seen many broken *Rhynconellas*, *Aviculas*, *etc.* The underlying Ore Sandstone at this locality might be mistaken at the first glance for a genuine limestone but it contains probably 60 per cent of silicious material, is very massive, and more than double its usual thickness.

The Barree Lower shales, green in color with thin limy fossiliferous layers are exposed also along the river bank below the furnace. The surfaces weather to an olive green. These shales when cut by the numerous tunnels driven across the measures into the foot slope of Tussey mountain

† At Mumper's on the N. bank of the Little Juniata the rock has long been quarried for flux, but only the 6′ or 8′ of upper layers. This upper part of the deposits gives 96, while the lower gives only 91 per cent carbonate of lime (T3, 224)

to reach the underlying Ore Sandstone and Fossil Ore bed, are nearly always decomposed into a mushy clay, some of it nearly *black*, which invades the tunnel from all sides, like a quicksand, and can only be kept out by a system of "Four-poling."

The *Sand vein ore bed* of the Juniata Valley described in the last chapter, and mined at Orbisonia in Southern Huntingdon, does not appear over the *Ore Sand rock* along Tussey mountain, in Huntingdon county, but becomes the principal mining horizon in Bedford county.

The Ore Sandstone. This is a somewhat ferruginous and limy sandrock, weathering at its outcrop (by the loss of its lime) into a coarse, porous. dark gray, excessively hard, sandy stone, often streaked with thin quartz veins, which are the deposit of gelatinous silica in cracks. It seldom makes a rock outcrop; but rather a well defined low ridge, the surface of which is strewn with blocks of various sizes up to 4′. Where anticlinal rolls repeat the outcrop there are as many distinct little ridges; the lowest of which runs as a distinct terrace along the mountain slope. As said above, at Barree Forge, the rock might be mistaken for a genuine limestone.

The Danville ore bed under the *Ore sandstones* sometimes exists and sometimes is wanting; varying greatly in thickness up to a maximum of 3′; but the average thickness cannot be safely stated at more than 1½′. As usual in all parts of the State the bed underground deep enough to be beyond the reach of the drainage water is a hard and somewhat silicious limestone, holding an original charge of iron amounting to only 20 or 30 per cent; the carbonate of lime making from 40 to 60 per cent; and therefore it is used by furnace men as an enriching flux with the soft ore. The soft ore goes down in the bed to a level marked by the lowest springs in the neighborhood; for to this depth the lime has been leached out of the bed, leaving a porous honeycomb silicous *soft block ore.* The unchanged ore is called hard block ore. In localities where the bed originally contained more alumina and less silica its dissolution has resulted in the production of ordinary soft fossil or "Keel ore." In many places the ore bed is double with a central slate parting varying from 1″ to 5″; the layer of ore above it being called the Big bed; that below it the Middle bed, the which latter is almost always changed to *Keel ore.* At Orbisonia the ore bed just under the sandrock is 4″ to 6″; an ore bed 4′ beneath it is 10″ thick. These beds are not worked (T3,139).

Ten analyses of samples taken at various places in Penn and Walker townships, Huntingdon county, as far south as the Stolertown mine in Bedford county, made by Mr. McCreath, showed the following percentage of iron 49.8; 50.9; 52.1; 52.4; 53.3; 53.9; 54.7; 55.0, and 55.5. In this range of analyses the silica ranged 3.8; 7.0; 8.4; 9.7; 12.5; 13.7; 14.0; 14.7; 14.9. In eight of them the lime ranged from .007 to 1.96. In ten specimens the phosphorus ranged from 0.129 to 0.804. In eight of them the sulphur ranged from 0.002 to 0.016. In four of them the magnesia was determined to be 0.129; 0.173; 0.223; 0.360. These analyses represent the ore when dried in the laboratory. In the practical working of the iron furnace the best output yields only about 40 per cent of iron and most of the stock not more than 35 per cent.

The foot slope of Tussey mountain and the rolling low ground in front of it have been extensively explored and mined between the Little Juniata and Bedford county line, say 25 miles of outcrop. The practical result has been the certain determination that this fossil ore deposit is not continuous as formerly imagined; that it offers valuable mining ground in three or four neighborhoods, the number of which may perhaps in the future be somewhat increased, namely, one north of the Little Juniata in West township called the Barree Forge mining district; none in Porter township; one in Walker township, the Kurtz-Grubb district about a mile long; one in Penn township, the Patterson-Grove district, not more than 2½ miles long; one in Lincoln township, the Kittie Houp district not more than ½ a mile long; and none in Hopewell township.

A large number of abandoned tunnels driven at considerable expense into the mountain all the way between the

Juniata river and the Maryland line are good evidence how little the men who call themselves "practical miners" can tell the character of the ore underground by inspecting what they call the "lay of the land" on the surface; that is the shape of the ground; which in fact merely guides the geologist to the place of the bed but gives no information respecting its character and condition; these being discoverable only by mining operations. The only indication which the surface occasionally yields is got from the weathered condition of the sandrock; for, where the weathering has evidently gone to a great length there the bed for an unknown depth may be presumed to be in a softened condition; but that does not tell whether the original charge of iron in it was large or small. If the ore bed was originally rich the weathering by softening it has made it a valuable mining ground; but where the bed was originally poor in iron no amount of weathering could make it a rich ore bed. The lime rocks weather into clay and the underlying shales are bleached almost white, being apparently deprived of their iron by transference. There are places along the foot of the mountain in Huntingdon county where it looks as if some of the iron in the ore bed had originally been an element in the overlying sandrock and had been transferred downward to the bed by the rain waters, which could not descend deeper through the strata because the underlying shales formed a water bed. This view however is not sustained by facts observed at other places; especially in the continuation of the range southward through Bedford county, where the principal fossil ore bed is not the *Danville* underneath the sandrock, but the *Sand Vein* on top of it; and the same is true along the Orbisonia range in Huntingdon county (F, 160) where however both ore horizons exist.

One thing however seems to have been discovered in these mining operations, namely, where the rainfall descends the slope of the mountain in a straight unobstructed water channel to the outcrop of the ore bed (where the porous and limy rocks permit it to sink into the earth) the ore is usually good. Where on the contrary the stream bends to the right or left and cuts its way in a channel back of the ore bed, leaving it on a ridge separate from the mountain slope. the ore bed is usually a lean ferriferous limestone.

Three sections exhibited by the Stoler, Weaver and Pincher tunnels, taken from T3, 136, 138, will give a sufficiently accurate idea of the places and attitude of the fossil ore bed on the foot slope of Tussey mountain.*

Stoler tunnel, dip 44° to 45°.

Red rock,	25′
Bluish gray shales,	77′
Red shales,	70′
Olive shales,	60′
Blackish clay (once lime shales),	48′
Olive and yellow shales,	48′
Blackish clay (once lime shales),	82′
Olive and blue gray shales,	63
Fossil ore bed (*no Sandrock over it*).	

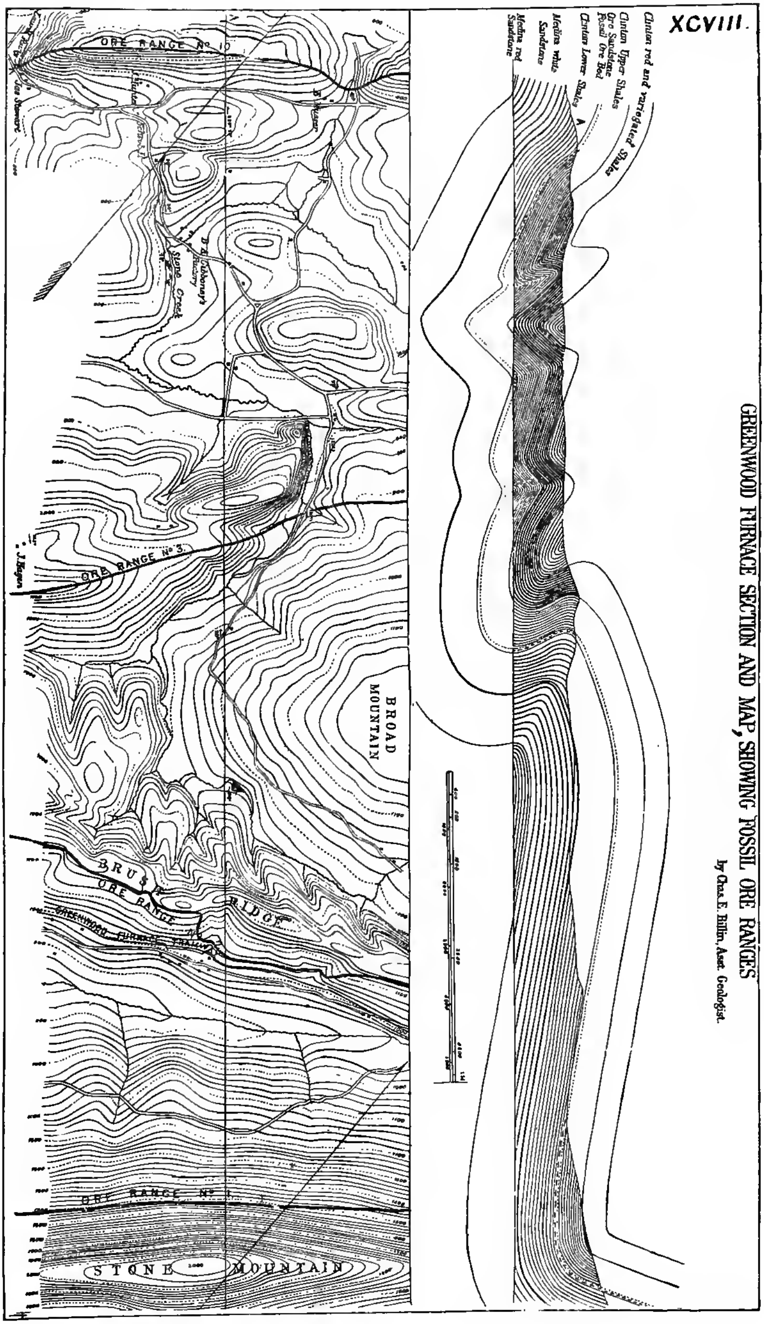
Weaver tunnel (T3, 162.)

Salina magnesian limestones,	100′	161′
Red shale (dip 40°),	5′	
Buff limestone,	3′	
Red shale,	5′	
Green lime shale,	10′	
Red shale,	8′	
Red and green shale,	5	
Red Sandstone massive,	25	
Concealed to tunnel month (dip 40°)		300
Concealed and blue limestone in tunnel.	100′	160′
Olive and gray shales,	50′	
Ore sandstone,	10	
Fossil ore, hard, limy, 6″ to 10″ thick.		

Pincher (*Fouse*) *tunnel* (T3, 172).

Concealed by timbers (180′ at 35°),			103′
Yellow, bluish, greenish shales, and hard layers (525′),			300′
Ore Sandstone	gray sandstone,	4′	15′
	"bogus iron ore,"	5′	
	slate and flagstones,	6′	
Danville? ore bed, hard lean (22 per cen.t),			5′
Slate and clay flagstone layers,		7′	47′
Gray sandstone with slate partings,		8′	
Hard lead colored slate,		9′	
Clay and slate parting (3 inches),		—	
Hard gray sandstone,		23′	

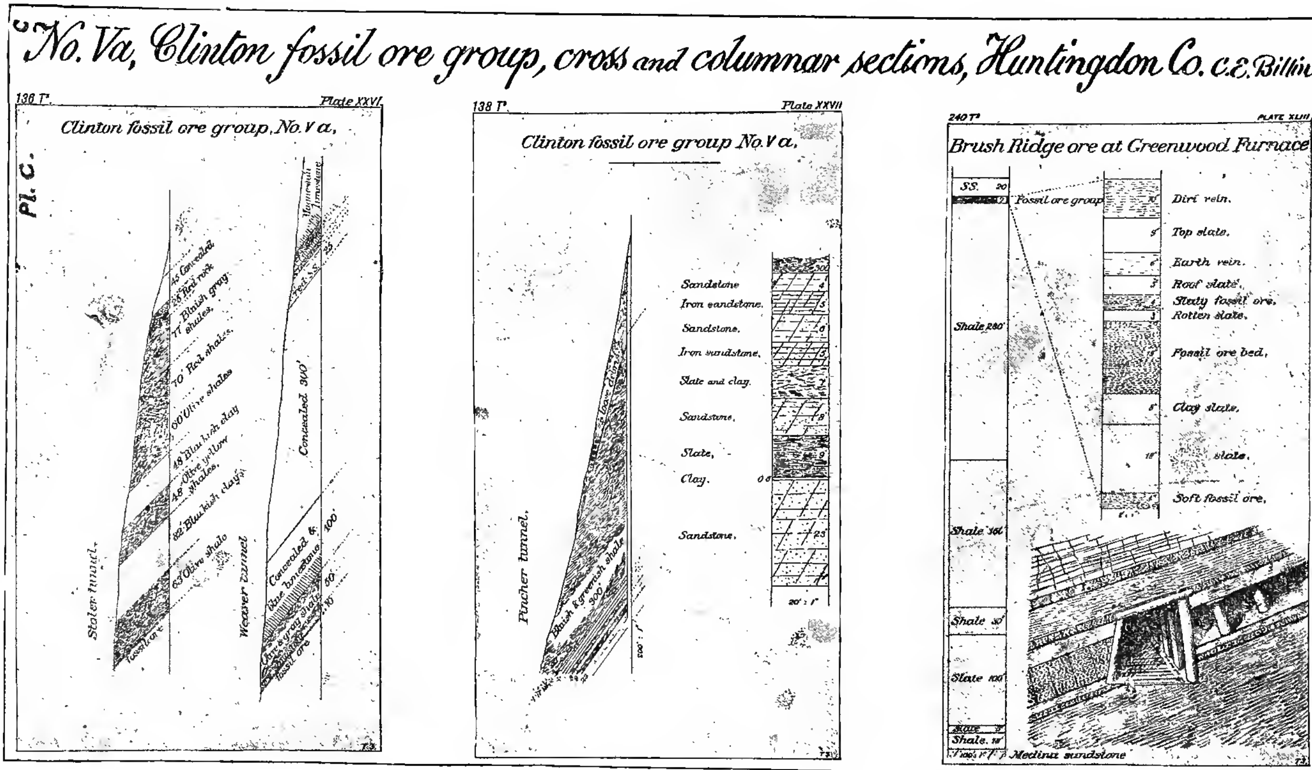
*The thicknesses given above are calculated from the record of horizontal distances driven in the tunnel, (T3, 161).



XCVIII.

GREENWOOD FURNACE SECTION AND MAP, SHOWING FOSSIL ORE RANGES

by Chas. E. Billin, Asst. Geologist.


C No. Va, Clinton fossil ore group, cross and columnar sections, Huntingdon Co. C.E. Billin.
138 T. Plate XXVI
Clinton fossil ore group. No. V a,
Pl. C.
Stoler tunnel.
45 Concealed
28 Red rock
77 Bluish gray shales.
70 Red shales.
60 Olive shales
48 Bluish clay
48 Olive yellow shales.
82 Bluish clay.
63 Olive shale
fossil ore
Weaver tunnel
Magnesian limestone
Red S.S. 25
Concealed 300'
Concealed & 100'
blue limestone 50
fossil ore
138 T. Plate XXVII
Clinton fossil ore group No. V a,
Pincher tunnel.
loose debris
Bluish & greenish shale 300
Sandstone
Iron sandstone.
Sandstone.
Iron sandstone.
Slate and clay.
Sandstone.
Slate.
Clay.
Sandstone.
20' : 1"
240 T. PLATE XLIII
Brush Ridge ore at Greenwood Furnace
SS. 20
Fossil ore group
Shale 280'
Shale 160'
Shale 30'
Slate 100'
Shale. 18'
Medina sandstone
Dirt vein.
Top slate.
Earth vein.
Roof slate.
Slaty fossil ore.
Rotten slate.
Fossil ore bed.
Clay slate.
slate.
Soft fossil ore.

Here there is a great development of sandy deposits *under* as well as *over* the ore bed, which only illustrates the impossibility of establishing any fixed rule of order of deposits except of the most general and vague or precisely local character.

The Greenwood Furnace ores.

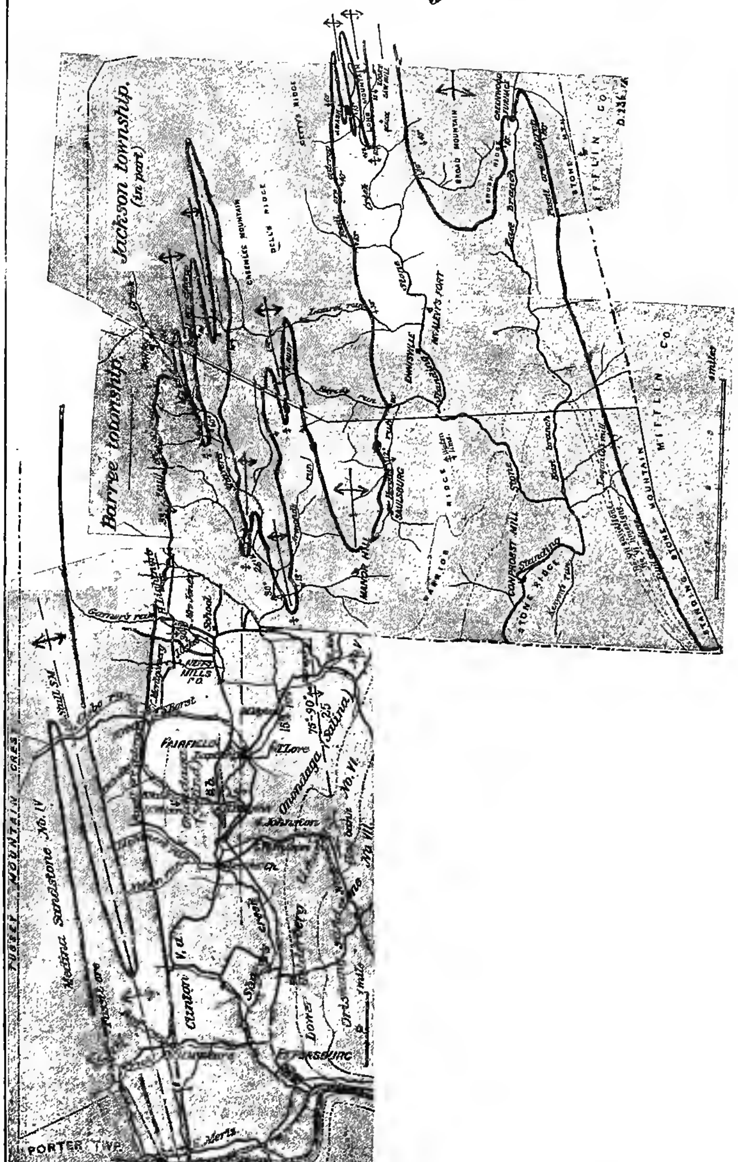
The Greenwood Furnace district of eastern Huntingdon in Jackson and Barree townships, has been a mining center of the Danville fossil ore for many years. The sinuous outcrop of the principal ore bed extends for more than 60 miles backward and forward in long and sharp zigzags, and across the head of Stone valley, and up and down the narrow ravine-like valleys between the many prongs of the Seven Mountains. All the openings, with the exception of those on Brush ridge near Greenwood furnace parallel to and back of Standing Stone mountain, were made about 1850 and have been long ago deserted Along most of the outcrops the ore bed dips at very steep angles, sometimes nearly vertical. The dip in Brush ridge is gentle (10° to 15° toward Stone mountain) and the ore bed crops out under a steep cliff of Ore Sandstone. The principal mining operations have been confined to the southwest end of Brush ridge, as shown in local map T3 sheet 3. Owing to the steep dip in Stone mountain the Ore Sandstone is thrown high up upon the terraced slope ; there are few ravines and where the ore beds are exposed they contain little soft ore.

The following section of Lower Clinton strata in Brush ridge made by Mr. Billin shows the *Danville bed* (under the Ore Sandstone) to be sub-divided into at least five distinct layers separated by partings of shale of variable thicknesses. No trace of the *Sand Vein ore bed* (above the Ore Sandstone) here exists ; and no *Iron Sandstone* or Block Ore is known in the 600′ of strata between it and the Medina sandstone.

Comparing this section in eastern Huntingdon with the general section in Bedford county last given, the two districts being 50 miles apart, their coincidence in one respect is most remarkable, the upper fossil ore bed of Bedford

Cl.

No. Va, Clinton fossil ore outcrop zigzags in eastern Huntingdon Co. C. E. Billin.



county being placed by Dr. Stevenson 586′ above the top of IV ; at Greenwood Furnace Mr. Billin makes it 600′ ; but the Greenwood bed underlies the Ore Sandstone and the Bedford bed overlies it.

Brush Ridge Fossil Ore Section, Greenwood Furnace. (T3, 239).

Ore Sandstone; bottom layers filled with vertical seams of lean earthy limonite; with fossils,			say 20′
Ore	Dirt vein,	8″ to 12″	say 7′
	Top slate, gray or yellow, compact,	7″ to 10″	
	Earthy vein, sometimes minable fossil ore,	4″ to 8″	
	Slate, yellow, compact (slope roof),	4″ to 5″	
	Fossil ore slate,	1″ to 6″	
	Slate, yollow, rotten,	3″	
	Fossil ore, main bed,	18 ′ to 20″	
	Clay slate,	7″ to 8″	
	Gray slate,	24″ to 36″	
	Soft fossil ore mined in gangway),	1″ to 6″	
Shale, dark gray, with some hard fossil sandstone layers, fossiliferous limestone, fossil ore,			280′
Shale, yellow and weathering dark-brown,			say 160′
Shale, greenish, dark-gray, occassionally red or olive,			say 30′
Slate, yellowish gray, sandy, weathering brown, breaking into long fingers,			say 100′
Slate, hard, dark gray with some sandy layers,*			5′ to 10′
Shale, light yellow,			10′ to 25′
Medina sandstone No. IV dark and light greenish gray sandstone, compact, iron specked,			—

The Ore Sandstone bottom layers are very siliceous, thin bedded and brittle, the upper 8′ or 10′ is quite massive and very fossiliferous, full of fragments of the stems of stone lilies (Encrini). Owing to its constitution its fragments are much scattered over the surface and when weathered have a rotten worm-éaten appearance and dirty yellow color. It is a guide to the ore (T3, 241). The Ore Sandstone is a yellowish, coarse-grained rock with vertical seams, through which the surface water has reached the ore beds and softened them. In drift No. 31 the sandrock is a hard bluish gray, unbroken quartz rock and the ore bed beneath it is a limestone. The general folding of the

*Compare the Block ore in the Bedford county section.

country by side pressure has produced a multitude of small faults from 6″ to 4′ encountered in the mines; and such faults are no doubt universal throughout this district and would be found traversing the ore bed whenever it was mined. In some of the mine drifts the rocks are very much rolled and faulted.

The following two analyses of hard and soft fossil ore from the same drift in the Brush ridge mines will illustrate their differences:—metallic iron 30.60, 50.48; insoluble residue 6.25, 21.33; phosphorus 0.527, 0.177. No account is here taken of the carbonate of lime which was a large item in the hard ore.*

The Clinton Middle shales along Tussey mountain, called bottom slates by the miners, make a broad outcrop belt on the mountain slope, marked by poor soil and a different vegetation and are so covered by sliding *débris* from the mountain above that they are to be studied only in three or four tunnels exploring for the Block Ore at their bottom. They seem to be about 600′ thick and to consist of fine-grained yellowish or bluish shales, passing down into reddish shales and gray sandy beds, becoming quite sandy at the bottom. (See descriptions in township reports T3, 139.)

The Iron sandstone forms a second bench or upper terrace along the mountain slope, varying from one-third to half the way up to the summit. This bed here attains a remarkable development. At one artificial exposure near Marklesburg it measures 36′ in thickness; all of it hard siliceous block ore, except about 4′ of soft ore in the middle of it. There are no natural exposures of the bed along the mountain side and it is only known where it has been cut through by the mining operations. It was once extensively mined near Marklesburg by the Cambria Iron Company. but was abandoned as holding too much silicon and phosphorus. It is an oolitic hematite, coming out in thin slab-like blocks, and the quantity of ore, such as it is, is necessarily very great. Three analyses taken, first, from the

*Various other analyses of the ore and pig metal and details of the outcrops can be found in Report T3, pages 246–255.

Cambria Company's mine; second, from Short mountain south of Barree Forge; and third, from Hatfield and Phillips' tunnel in the Loop back of Alexandria show the following constitution: Iron 44.25, 41.10, 33.475; manganese 0.147; silica 27.91, 25.95, 36.200; alumina 2.66, 3.93; lime 0.52, 0.29, 1.880; magnesia 0.26, 0.23; phosphorus 0.68, 0.50, 0.609; sulphur 0.025. (See special descriptions in township reports T3, 140.)*

The Clinton lower shales along the Tussey mountain are everywhere effectually concealed, outcropping between the Iron Sandstone terrace and the rocky and wooded belt of the mountain slope. The block ore or Iron Sandstone has always been supposed to lie here directly upon the White Medina sandstone, No. IV; but in a wide railway cutting along the Little Juniata above Barree Forge the following section appears (T^3. 221, 222):

Ore sandstone, ... 25′
Danville fossil ore, a thin limestone.
Concealed along the RR. westward from this cut, to Barree station and for the 300 yards further.
Clinton middle shales, 1400′, dip 20°= . . . . 480′
Concealed space, in which *pieces of block ore* are seen on soil, ... 100′
Olive and reddish sandy shales, dip 20° . . . . 405′
No. IV. *Medina* gray and white sandstones.

If the fragments of block ore here seen belong to the block ore of the mines to the south, the supposition that the latter lies very close to No. IV must be a mistake; and yet the only place in Bedford county where block ore has been opened for mining operations, and found to be only 2 feet thick, is supposed to lie only 10 feet above No. IV (T^2, 90, 91, 327). It is hardly likely that 400′ of shales on the Little Juniata thin away to 10′ in Bedford county; it is more likely that the block ore beds are different.

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*Sometimes the *block ore* is very rich. From a drift near the crown of the second roll in Penn township, Mr. Patterson has mined a ton of ore per square yard of surface from a 15″ to 24″ bed, yielding large rectangular blocks of ore, three samples of which showed: Iron 54.95, 52.40, 53.90; silicious matter 9.69, 14.86, 12.51; lime 1.13, 0.07, 0.07; sulphur 0.012, 0.009, 0.011; phosphorus 0.469, 0.129, 0.138.

The block ore in Short mountain (spur of Tussey mountain) is too siliceous for furnace use. A Cambria analysis showed: Iron 41.1, silica 25.9, alumina 3.9, lime 0.29, magnesia 0.23, phosphorus 0.5 (T^3, 223).

Chapter LX.

No. V in Bedford and Fulton Counties.

No attempt was made in these counties to separate the Salina, Niagara and Clinton formations in the body of the text of Report T2, by Prof. Stevenson; who gave 158′ to the Oriskany; 336′ (on the Maryland line) to the Lewistown limestone of No. VI; 283′ to the Cement beds (Tentaculite limestone of New York); 628′ to his lower division of No. VI; 275′ to his Salina and Niagara beds, including the Redstone ridge beds along Black valley; and 894′ to his Clinton No. V.

As Prof. Hall many years ago came to the conclusion that the thin *middle division* of the eastern New York *Water Lime* formation (the upper division being the Tentaculite limestone) represents the thick *Salina* formation of western New York, while the thin *lower division* represents the thick *Niagara* formation of western New York,—as the Survey of Pennsylvania corroborates that opinion,—and as the Cement beds have been taken in Pennsylvania to be the bottom division of No. VI,—it is necessary to readjust the classification adopted in Report T2, thus:—Oriskany No. VII, 158′; Lower Helderberg No. VI, 619′; Salina (and Niagara?) No. V, 628+275′+197′=1100′; Clinton No. V, (from the Saltillo fossil ore bed down to No. IV), 700′.

Neither this nor any other adjustment of these formations can ever be entirely satisfactory, on account of their excessive variability, and on account of the irregular distribution both of the fossil forms, and of the hard and soft layers in which these fossil forms are abundantly accumulated. It is nevertheless satisfactory to find so close an agreement between the two geologists, working independently of each other in Bedford and Huntingdon counties, as to the total thickness of deposits from the base of No. VII down to the top of No. IV; the former making it 2489′; the latter 2982.′ The difference of 500′ may represent an actual thinning of deposits southward, such as is known to take place through Virginia; but it may also be occasioned by the difficulty of measuring the total thickness at any one locality. There is also room for the supposition that the lowest division of the Clinton, on top of No. IV, the outcrops of which are everywhere concealed beneath the *débris* of the mountain slopes, has been mystified by uncertainties respecting the number of Iron Sandstone or Block Ore layers; seeing that in Huntingdon the interval between the Block ore and and No. IV is made 400′ and in Bedford only 10′. If this 400′ were taken from the total thickness in Huntingdon (2082′), the residuum (2582′) would be very nearly the 2489′ of Bedford county.

The Salina Upper and Middle divisions in Bedford county (628′) consists of lime shales varying in color from drab to reddish, and including thin layers of limestone. The Cumberland road south from Bedford runs for most of the distance on the outcrop of this formation. In Fulton county it is fairly well shown near Fort Littleton. Toward the bottom of it are local impure limestone beds, quarried for farm use. The only fossils seen in it is the *Leperditia.*

The Salina Lower (472′) (including perhaps *Niagara* beds at the bottom), is partly shown in the tunnel near Tatesville, the upper beds being a hard red shale and red sandstone. The highest bed is a red sandstone or fine-grained grit (15′ to 20′), showing films of quartz honeycombing the mass, making Red or Rocky ridge in Bedford county.

Underlying this are alternations of red and yellow shales, fairly well exposed at many places in north Bedford county; but in Fulton county where the red shales are as distinct a formation as elsewhere, the *top rock is wanting*, and consequently there is no Red or Rocky ridge. No fossils occur in any of the upper 150′ of strata, and there is no appearance of salt deposits.

Under these (Bloomsburg) red shales lie thin limestone layers separated by variegated shales, making a gradual passage downward into the Clinton. The limestone layers rarely exceed 6″ in thickness and fossils are seen only in the highest of these beds; but this one bed is in many places crowded with specimens of an unnamed fossil *Trematospira*. This group may perhaps be adopted by some geologists as the representative of the *Niagara*.

General section of Clinton strata (*T2, 90*).

Shales, red and yellow,		197′	
Fossil ore bed,		10′	
Shales, green, yellow and purple,	385′		
Frankstown ore bed,	1′		894
Shales, green and yellow,	288	686′	
Block ore bed,	2′		
Interval to Medina No. IV,	10′ ?		

The 197′ of shales at the top of the section are rich in fossils at many horizons and show such a mingling of Clinton forms with Niagara forms, as to make it impossible to assert that the Niagara formation is represented or is not represented in this part of Pennsylvania. These shales are nowhere in Bedford and Fulton counties well exposed to study, and they may be placed in the Bloomsburg red belt or in the Clinton at will. In any case the general section has not the authority of a total section such as that made by Prof. Stevenson along the Bedford and Chambersburg pike, commencing at the limestone quarry directly opposite the bridge and going (westward) to Dunnings Narrows, or the gap of the Raystown branch of Juniata through Evitt's mountain.

Dunning's Narrows section (*T2, 191*).

Concealed from base of No. VII, *Oriskany*, down,	35′?
Limestone, argillaceous, somewhat slaty; weathers dirty yellow; cherty layers at the base,	20
Limestone, very cherty, hard, blue; in layers 2″ to 10,″	9′
Limestone, compact, clear grey; quarried; good, but not perfectly white lime,	18
Limestone, with *Stromatopora*, slaty, bluish grey, varying from argillaceous to siliceous,	6′
Limestone, full of *Stromatopora nodules* and *balls* (1″ to 12″ diameter), nodular, bluish,	8′
Limestone, compact, blue; calc spar streaks,	3′
Limestone, more or less shaly; some *fossils*,	6′
Limestone, very siliceous,	7′
Limestone, with *Stromatopora nodules* and some other fossil forms, bluish gray,	60′=170′ ?

Unknown strata, dipping 50° eastward, ... say		525′
Limestone, slaty, blue, at Barndoler's, 46°	7′	
Unknown strata, calculated at 46°, ...	106′	
Shale on railroad, 46°	10′	
Limestone, magnesian, flesh colored, on RR., ...	12′	
Limestone and drab shale, ...	11′=146	
Unknown strata (260′ horizontal), ... say		182′
Eichelberger's brown hematite ore mine.		
Shale, limy, drab (mine cutting, 45°), ...	17′	
Unknown strata, for 350′ horizontal, ...	225′	
Shales, with *dendritic markings*, more or less fissile, yellow to drab, ...	18′	
Limestone, impure (40°), ...	11′	
Limeshale, ...	19′	
Dark shale, fissile, ...	12′=302′	
Sandstone, reddish brown, gritly, slightly limy, streaked with quartz films, ...	11′	
Red shale, ...	5′	
Sandstone, as above, but shaly at the bottom and much twisted, ...	15′	
Red shale, *badly exposed*, variegated towards the bottom; badly twisted at the engine house, where it holds some thin poor limestone layers, and (reported) a thin *fossil ore* (60°+ for 350′), ... say	300′=331′	

No. IV, Medina white sandstone upper beds, not fully exposed, in the bluff at the township line; bedding irregular and much twisted towards the bottom of the mass, which is about 344′ thick, with dips of 50°, 55°, 60°, 75°, eastward, averaging between 50° and 55°. The upper 100′ of Medina being very imperfectly seen, it is impossible to say if any *block ore* be here.

Comparing this with the general section given above, we see at once that *Eichelberger's brown hematite* bed occupies the place of the *Fossil ore;* one being 633′, and the other 686′ above No. IV; and that the *Red sandstone* group is on the horizon of the *Frankstown ore;* one being 310′, the other say 300′ above No. IV.

Fossil ore beds in Bedford county.

Three principal fossil ore beds occur in Bedford county. The upper and only important one is known simply as the *Fossil ore;* the middle one as the *Frankstown ore;* and the lower one as the *Block ore.* But besides these, some thin indefinite layers of no economic value whatever have been found here and there in the upper part of the Clinton formation.

The Fossil ore bed is mined at Powell's cove in Liberty; by the Kemble C. & I. Co. in Hopewell; by the same company and by Lowry, Eichelbarger & Co. in West Providence north of the river; is well exposed south of the river by Scott & Russel in West Providence; and at many places in Monroe and Southampton by J. B. Williams. Along the west side of Evitts mountain it has been prospected by Powel & Kerr and extensively mined by the Kemble Co.—On the east flank of Wills and Dunning's mountain it has been mined extensively by the Kemble Co.; and prospecting has been carried down to the Maryland line by Kerr and others. On the east side of Wills mountain it has been mined and prospected by Cessna and by the Cumberland C. and I. Co. and has furnished most of the stock for the Riddlesburg furnaces.—On the west side of Wills mountain it has been proved all the way from north of the Juniata to the Maryland line, and mined in Londonderry, Harrison and Napier townships.

In Londonderry township the bed is single, varying from 6″ to 23″; in Harrison the bed is double 18″ and 2″ of ore, separated by 24″ of sandstone, and is known therefore as the *Twin seam.* The 2′ of sandstone probably represents the *Ore Sandstone* of middle Pennsylvania thinned away almost to nothing. The ore is fine, yielding (old dried specimens) iron 45.2 and 40.9; sulphur 0.025, 0.013; phosphorus 0.454, 0.422; insoluble residue 21.6, 13.9 In Napier township the bed is triple, thus:—*top ore* 10″, shale 6″, sandstone 24″, *middle ore* 18″ running down to nothing; shale 15″, *bottom ore* (best) 10″.

In Cumberland Valley township the bed does not average more than 15″ although it is reported 23″ at one place and 36″ at another. In Bedford township near the southern line it is reported 14″. South of the Pittsburgh pike it has been only prospected and seems to be a single layer.

Opposite Wolfsburg north of the pike the section is:—*top ore* 8″ to 14″, shale 6″ to 12″, blue sandstone 24″ to 30″, *middle ore* 8″ to 18″, shale 18″, *bottom ore* 4″. Here the main supply is the upper bed, averaging 10″; the middle bed, very uncertain, sometimes cut out by the sandstone, and this seems to prove the truth of the suggestion made above that this very persistent sandstone parting really represents the *Ore Sandstone* of middle Pennsylvania; in which case we should have a right to name the top bed, *Sand Vein*, and the middle and bottom beds, *Danville*.

In Dutch Corner in the northwestern part of Bedford township are the Kemble C. and I. Co.'s mines. Two sections taken half a mile apart show these variations:—*top ore* 28″, 36″; shale 48″, 36″; *middle ore* 9″, 4″ to 2″; shale 4″, 12″; sandstone 11″, 18″; *bottom ore* 14″, 7″. Only the top ore is mined; being near the outcrop soft ore and strip; under solid cover it is mined as hard ore and the change takes place suddenly. It is remarkable that the sandstone in Dutch Corner lies between the middle and bottom ores. Three analyses from County Farm, from Wolfsburg and from Dutch Corner gave:—Iron, 44.4, 46.4, 25.7; sulphur 0.017, 0.011, 0.034; phosphorus 0.161' 0.344, 0.251; insoluble residue 22.3, 12.8, 9.0; carbonate of lime, blank, 11.6, 46.3; carbonate of magnesia, blank, 1.1, 2.6.

Along the west side of Evitts mountain the bed has been prospected at various places and mined by the Kemble Co. at Juniata gap, but abandoned, the section in the tunnel being:—*top ore* 12″ to 17″, sandstone 13″ to 30″, *middle ore* 4″ to 16″, sandstone 24″ to 30″, *bottom ore* 6″ to 20″. Here it is noticeable that the sandstone occupies both intervals, and clings so tightly to the ore beds that the miners will not furnish clean stock to the furnaces; and this has caused a stoppage of mining operations.

Black valley is the name given to the low ground at the east foot of Tussey mountain between it and Warrior's ridge all the way from Maryland to Huntingdon county.

The fossil ore bed has been proved by various parties and companies the entire distance of 40 miles. In most places the bed is double, the upper and more important layer being known as the *Fossil* and the lower as the *Twin*. Between the Juniata and the State line there are no mines, but three prospecting pits in Southampton township show:

—*top ore* 36″, 18″, 13″; clay 4″, 2″, 1″; *bottom ore* 15″, 10″, 27″. In all three the ore was very good the lower layer softer than the upper; the upper usually containing not a little brown hematite.

In southern Monroe the outcrop ore seems poorer containing small almond-shaped pieces of quartz. In northern Monroe numerous pits have been sunk and the bed sometimes shows at its outcrop nothing but brown hematite. Its total thickness in some of these pits is 6′ but the ore is not compact and the outcrop is probably broken up, the ore being however of very fair quality in all of them.

In West Providence, north from the township line, the Scott and Russel pits show the bed as variable as usual; for example: *top ore* 36″, 18″, 6″ to 8″; shale 6″, 38″, 3″; *bottom ore* 36″, 14″, 17″ to 20″. In one of these pits *four divisions* of the bed were noticed. The upper ore always contains some brown hematite and is often sandy.

Along this Southern Tussey mountain range six samples of ore were analysed, two in Southampton, two in Munroe and one in West Providence, as follows: Iron 48.1, 54.1, 53.8, 45.2, 17.1, 54.9; sulphur 0.017 to 0.025; phosphorus 0.161 to 0.723; insoluble residue 13.8, 7.8, 3.8, 22.6, 69.1, 9.6; and in the third, water was found to be 12.5. All the samples had been exposed to the air from two to five years, except the sixth which was taken out fresh; the fifth probably does not represent properly the ore.

In West Providence and southern Hopewell the Kemble Co.'s mines extend for more than three miles along the bed; and their tunnel strikes the ore at 325′ below the outcrop. The bed section is: *Fossil ore* 24″ to 72″; interval 72″ to 0″; *Twin ore* 2″ to 72″. In the top bed for 50′ from the surface down brown hematite and fossil ore occur together; below 50′ the bed becomes all fossil. A notable fact is recorded that at one place in the gangway (325′ below the outcrop) a nest of calcareous (hard) ore was struck, which excited fears lest the lower limit of the soft ore had been reached; but the bed soon resumed its character, although somewhat silicious. The variability of the bed in thickness has been exhibited by these mining operations to an unusual degree; the bed occasionally thinning to almost nothing and thickening again to far beyond its average. There is one stretch of more than a thousand feet of gangway in which the combined thickness of ore is nearly 12 feet, the parting here being reduced to a mere knife-edge.*

In Hopewell township, a mile south of Yellow Creek gap through Tussey mountain, a long tunnel was driven to some ochreous clay which was supposed to be in the proper place for the ore bed, but no ore was found; nor any along the outcrop. The miners invented a theory that no ore existed *south* (or west) of any of the great gaps. Had the Tatesville tunnel been driven further in, the miners might just as well have invented another theory that no ore existed *north* (east) of the gaps. The fact is the gaps have nothing to do with the ore deposits (T2, 325).

In the Cambria mine the ore runs from 2′ to 5′; in the Powel mines from 2′ to 4′. In Powel's Cove tunnel the ore is struck 240′ beneath its outcrop on the mountain side.

Samples taken at Tatesville,—at the Cambria mine in Hopewell,—and at Cove tunnel in Liberty,—gave iron 38.6, 55.4, 41.8; insoluble residue 31.0, 5.7, 35.6; sulphur 0.018, 0.018, 0.00; phosphorus 0.213, 0.226, trace; water ——, ——, 4.24.†

The fourth sample, labelled brown hematite from the Stoler farm, Liberty township, gave to Mr. Britton's analysis: iron 58.1; insoluble matter 4.1; sulphur 0.0; phosphorus 0.27; water 11.2.

Brown hematite outcrop of fossil ore bed.

The presence of *brown-hematite* iron ore, so frequently mentioned along the outcrops of the fossil ore beds, and even for 40′ or 50′ down the dip (in less and less proportionate quantity, until it disappears and the whole bed is fossil ore), is a noteworthy circumstance, bearing as much upon the theory of their origen as upon prospecting for and mining them. But seldom, at least in Pennsylvania, does it assume the importance which it does at the remarkable

* This reminds us of the 20′, 40′, 60′ beds of bloodstone ore in Tennessee.

† A duplicate from Cove tunnel gave, iron 44.36; phosphorus 0.023.

mine of Lowry, Eichelbarger & Co., at the sharp bend of the railroad, one-third of a mile southwest from Everett station. The place of this mine in the Salina series is shown in the Dunnings Narrows section last given. While this mine exhibits the grand features of the brown hematite mines of No. II, and of those like the Baker mine between Altoona and Tyrone City on the outcrop of No. VII, or at the top of No. VI, it occupies the horizon of the Fossil ore bed of No. V, and consequently must be connected in some way with the iron bearing lime-shales and limestones enclosing that fossil ore bed.

The workings cover many acres and have been prosecuted with more or less vigor for 50 years. The brown-hematite ore is distributed throughout an immense deposit of sandy clay, which shows by its obscure lamination that it is merely a mouldered down mass of lime-shales.† On the railroad the breadth of the excavation is great; but it narrows rapidly 60 rods back; and extends then as a deep broad cut 40 rods further, where the surface is from 40′ to 60′ above the railroad. A shaft was sunk 20′ deep in this cut; and numerous short tunnels have been driven from it sideways. A shaft 135′ deep, 50 rods from the railroad, struck limestone at its bottom. The western foot-wall of the ore-bearing clays, at the north end, is a black shale 3 or 4′ thick, but this soon sinks beneath the clay-mass approaching the railroad. The 17 foot drab shale of the section parts the clay-mass for 60 rods, and then disappears, allowing the two divisions of the clay-mass to come together. This of itself is a sufficient evidence that the clay-mass is nothing but the original lime-shales in a mouldered condition. The east wall has not been found, but the clay-mass evidently reaches the solid lime layers of VI in Mulberry ridge. The clay-mass, as proved by the deep shaft, is 190′ deep. How far it runs northward along the outcrop is not known.

The ore is irregularly distributed through the clay-mass,

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†This mine becomes of great importance in discussing the origin of the Cornwall magnetic ore mine in Lebanon county. See Annual Report for 1885.

as might be expected from the theory; and its lines doubtless follow what were originally the most ferriferous beds of lime-shale. One tunnel 40′ long cuts 20 distinct and different layers of ore varying in thickness from ½″ to 3″; they are all lens-shaped, thinning out in every direction. Such ore layers have been cut in all the tunnels. Much of the ore is lump-ore; but the greater part of it is small, and must be washed out of the clay. *No transported fragments of any kind were seen in the clay-mass.* This is another proof that we have here a great formation of lime-shales, locally decomposed or mouldered by water holding acid solutions. The original deposit of lime-shales were themselves universally charged with a certain percentage of iron, sufficient for the concentration of all the ore in the mine. A sample analysed for the Survey gave: Iron 42.6; insoluble residue 18.7; sulphur 0.099; phosphorus 0.182.

The Frankstown bed. The Frankstown bed will be described in detail directly in Blair county. In Bedford county it has nothing like the importance of the Fossil ore bed above it; but it appears to be a persistent horizon, although that cannot be certainly demonstrated; and it is possible that there is more than one, perhaps several beds, which may be easily mistaken one for the other at distant localities, the place of each in the series being hard to fix. One such bed certainly runs along the west side of Dunning's mountain in east St. Clair, and perhaps the same bed runs along the east slope of Wills mountain in Cumberland Valley township. But no such bed has been discovered on the west slope of Wills mountain; nor anywhere along the east slope of Tussey mountain facing the Black valley. In St. Clair township Powel found it 10″ to 12″ thick. In Cumberland Valley township it was got in at least two pits. Samples from the Geisler and the Bortz farms gave: Iron 49.5, 43.8; insoluble residue 20.5, 17.4; sulphur 0.02, 0.02; phosphorus 0.14, 0.54.

The Clinton middle and lower shales in Bedford county show no satisfactory exposures, although their outcrops form both slopes of Wills mountain, the west slope of Evitts mountain, and the east slope of Tussey mountain;

for the amount of stone-slide from the Medina outcrop in the upper third of the mountain is so great as to completely conceal them.

Block ore has been found on the west side of Dunning's mountain in east St. Clair township, Bedford county; on the east slope of Wills and Dunning's mountains in Bedford and Cumberland Valley townships; on the west side of Evitts mountain in Bedford township and on the east side of Tussey mountain in West Providence township. The bed seen in east St. Clair township contains some fossil ore; but in other exposures nothing but lumps of brown hematite are noticeable. The only attempt to mine block ore has been in West Providence, where a bed only 2′ thick was opened (T^2, 90, 91, 327). The amount of ore appears to be considerable at the head of the Juniata gap through Evitts mountain.

Chapter LXI.

No. V in Blair county.

Facing the Allegheny mountain is a continuous mountanous outcrop of No. IV, known in Bedford and western Blair as Wills (Buffalo) and Dunning's mountain and in eastern Blair, Centre, Clinton and Lycoming counties as the Bald Eagle mountain. The whole length of the range from the Maryland line to the bend of the West Branch of the Susquehanna at Muncy is 150 miles. In Blair county a break in the range exists between the southwestward dying end of the Nittany valley anticlinal at Frankstown and the northward dying end of the Morrison's cove anticlinal at Hollidaysburg; and this break is the western entrance to the *Frankstown cove*, a hatchet-shaped synclinal basin filled with Formation No. VIII. A similar break exists near Bedford, between the southern dying anticlinal of Morrison's cove and the northward dying anticlinal of Wills and Buffalo mountain. Between these entrance is in a similar manner given from the west to the oval synclinal trough of Dutch Corner (north end of the Bedford trough), filled also with Formation No. VIII.

Between this mountain range and the Allegheny escarpment lies a long narrow trench-like valley uninterrupted from end to end, produced by the outcrops of Formations VI, VII, VIII and IX, descending westward and northward under western and northern Pennsylvania, to appear again at the surface in Ohio and New York. The slope of the mountain facing the Allegheny is made by the broad outcrop of Formation No V, dipping almost everywhere at high angles from 50° to 90° and in one or two places even slightly overturned; Clinton Lower shales rising nearly to the top of the mountain slope the Salina lime shales and limestones running along the valley at the foot of the mountain; the Bloomsburg red shale strongly marked everywhere, and the fossil ore beds opened in many places, especially where they sweep round (with low dips), the ends of the two anticlinals in Bedford, and the ends of the two anticlinals in Blair; the Frankstown mines being old and extensive.

Not only along the mountain slope facing the Allegheny, but also encircling the Frankstown cove and the Dutch Corner cove, the Clinton outcrops carry the fossil ores; but nowhere have these been extensively mined or thoroughly tested except at a few places well situated for transportation. The Clinton side of this mountain range is drained, as has been already mentioned, by shallow rills which offer poor exposures; and it may be that in the future valuable stretches of ore ground will be found where at present they are not suspected; but it must be said that exploration pursued almost continuously now for half a century has resulted in an apparently well founded conviction that the fossil ore beds are in most places too thin to be worked or too steep to be changed into soft ore; and even when so changed near the surface they become hard, and lean a few yards underground. At all events such is the state of things all the way from Tyrone City in Blair to beyond Williamsport in Lycoming In fact it has become a recognized fact that the ore beds of this range cannot be worked to profit except where the dip flattens as the outcrop approaches and turns round the dying ends of one of the anticlinals, as at Frankstown, Hollidaysburg and the vicinity of Bedford. Mining has been attempted in past years in the Centre county gaps and abandoned. No exhibition of the ore appears in the gap of the Little Juniata at Tyrone City; but in the Raystown gap just east of Bedford the steeply dipping ore bed has been mined with good success.

The place of the principal Frankstown Ore beds in the series is in a general way well defined, but its exact height above No. IV was not determined with precision by the instrumental work done in Blair county; the great shale mass underneath it being everywhere more or less concealed and only to be got by calculation from a measured line in connection with the dips of the overlying rocks. This calculation gave 720′ as seen in the following section (T, 16), which for the sake of clearness will be commenced at the Oriskany sandstone No. VII on top and continued down to No. IV, a total thickness of nearly 2300.′

Blair County Section.

No. VII. Oriskany sandstone with coarse grained conglomerate layers,			about 50
No. VI. Lower Helderberg (Lewistown limestone) partly exposed, mostly dark blue, massive limestone beds; as measured at Chimney rocks near Hollidaysburg,			900′
No. V. Salina and Clinton limestone, gray, slaty,		120	
Concealed interval,		30′	
Gray slate with limestone layers,		60	
Dark gray slate,		5′	
Limestone, slaty,		14′	
Limestone,		1′	=230′
Bloomsburg Red beds,	Gray Slate,	3′	
	Red shale,	26	
	Gray slate,	1′	
	Limestone,	0′ 10″	
	Gray slate,	5′	
	Green shale,	0′ 6″	
	Red shale,	1	
	Gray shale,	1′	
	Red shale,	14′	
	Gray slate,	5′	
	Bastard limestone,	1′	
	Brown slate,	5′	
	Olive slate,	2′	
	Red slate,	7′	=73′
Limestone layers, small, in gray slate,			45′
Limestone, dark blue, fossilferous,		1′ 9′	
Gray slate,		1′ 6″	
Limestone,		1′ 6	
Gray slate,		4′	
Limestone,		0′ 2″	
Olive slate,		30′	
Limestone,		3′	
Gray slate,		3′	
Limestone,		2	
Gray slate,		6′	= 52′
Red beds.	Red shale,	2′	
	Oliveshale,	3′	
	Red shale,	6′	
	Green shale,	2	
	Red shale,	3	
	Olive shale,	2′	
	Red shale,	6′	= 24

Gray shale,	5′	
Gray slate, partly concealed,	30′ =	35′
Fossil ore beds in a concealed interval,		50′
Gray slate,	20′	
Concealed interval,	30′	
Brown slate,	30′	
Concealed interval,	640′ =	720′
No. IV. Medina white sandstone at the bottom,		——

The section here given is of great value as an example of the alterations of thin limestone beds and shales of marked difference in color, gray, olive and red, characteristic of the Salina group ; but it is so defective in the lower or Clinton division as to be of little value ; for it conceals the important fact that two ore horizons exist beneath the one mentioned in the section which, from its height above No. IV, must be at the horizon of the Ore sandstone. The information thus witheld is supplied by the notes of Mr. Brawley, chief miner of the Cambria Iron Company at Hollidaysburg, from which a section has been constructed, on the basis of the topographical contour line map made for the survey by Mr. Sanders (T, 137).

Hollidaysburg (Cambria Iron Co.) Section.

Upper (Saltillo ?) soft fossil ore bed varying from, 3 to 8 inches.			
Reddish and some olive slates and shales,			50′ to 100′
Sand vein ore bed, lean and poor,		1′ 4″	14′
Ore Sandstone { Slate, 3′ to 4′; Sandstone, brown, 8′ }		12′	
Danville ore beds, fossiliferous,		1 1″	
Reddish and other concealed shales with thin sandstone and "ore pin".			400′
Frankstown fossil ore bed, varying from			8″ to 1′ 10″
Chocolate colored slates.			20′
Reddish slates, and sandstones etc.,			180
Hard fossil and "Keel" ore, sandy and worthless,			2′ to 10′
Reddish sandstones, etc, supposed to be about,			100′
No. IV White Medina sandstone.			

It has been often asserted that the Ore Sandstone along the Bald Eagle outcrop of No. V is absent ; that the deposit did not extend thus far westward ; but it is evident from the above section that it is represented by the 8′ of brown sandstone between the two ore layers, which together have received at Hollidaysburg the local name of the *Double* *ore bed;* and which we can hardly doubt represents the *Sand Vein ore bed* above and the *Danville ore bed* below the sandrock. No doubt in a thousand places along this extensive outcrop the sandrock is wanting and with it one or the other or both of the ore beds.

The *Saltillo? or upper soft fossil ore bed* has been opened at numerous places in Blair county but nowhere found minable. On Cove mountain it is a poor bed 3″ or 4″ thick. At one place in east Hollidaysburg it was opened as a poor sandy block ore, highly fossiliferous 14″ thick. Several small limestone beds crop out beneath it. A mile west of Hollidaysburg it is a lean ore 12″ thick, under which lie gray slate 2″, limestone and some ore 6″, slate 8″, limestone 3″, slate 4″, limestone and some ore 2″, slate 2″, very lean and poor ore 7″, limestone and slate 10′.

The *Sand Vein fossil ore bed* (upper layer of the Double ore bed) has been opened at various places in Blair county. In the town of Hollidaysburg it is covered by slate 6″; over that, limestone, ferriferous, 4″; over that olive and gray slates 15′ to 25′. An analysis shows:–metallic iron 21.600; metallic manganese 0.035; sulphur 0.024; phosphorus 0.477 and this is supposed to be a fair average.

The Danville ore bed (lower layer of the Double ore bed) here sampled, gave on analysis:—iron 13.500; manganese 0.032; sulphur 0.034; phosphorus 0.182. It is therefore merely a ferruginous fossiliferous limestone bed.

At Baker's mine three miles south of Altoona the section is as follows: upper ore 9″, gray slate 24″, lean specked ore 10″, slate sometimes as much as 6″; massive limestone 5 feet; slate 1′ 6″; bastard limestone 3′ 6″; slate and bastard limestone 3′ 4″; lower ore bed 13″. Here there is not a trace of the Ore Sandrock, but in its place are massive limestone layers. While the upper bed contained only 20 per cent of iron, the lower bed contained 48.5 per cent, with manganese 0.090; sulphur 0.030; phosphorus 0.197. The average yield of iron, however, in the furnace was only about 35 per cent; and only one-fourth of this fossil ore is used as a mixture with three-fourths of the brown hematite from the great mine near Altoona. The variations in these fossil ore beds are simply infinite. At one place a 9″ bed of ore overlies the lower fossil ore bed about 18″; and 4′ higher is another varying from 4″ to 6″. The lean spotted ore bed is 16″ at one place and 26″ at another. So uncertain is the mining of this Double bed that the Baker mine is the only work in the county but the outcrop line of the ore is so continuous and extended that it would certainly be mined largely if an active demand for ore of this grade should ever arise. In some places only one layer in the whole group has been found and that too small and lean to work; as for example on the slope of Short mountain west of the gap. In fact along the outcrop from Short mountain gap to Dry gap this Double bed has been thoroughly explored and been found everywhere poor except on one farm. Sarah furnace has opened it on the east side of the end of Dunning's mountain. From Dry gap to McKee's gap south of Hollidaysburg there are numerous openings on it and it is usually found in a soft condition. At McKee's gap it has been mined for Martha furnace. On the Duncan property back of the reservoir the bed is reported 3′ thick. The very numerous old pits along the Loop mountain slope have been abandoned. It has been opened also along Brush mountain in Scotch Valley north of Frankstown.

Dysart's mine opposite Tipton, high up the mountain side appears to be on the horizon of the Ore Sandstone, and to have both the Sand Vein and the Danville ore beds. The short tunnel commenced with a top shale holding soft fossil ore, 8″ thick; then struck the Ore sand rock, 16′ thick; under which lay fossil ore, hard, lean 1′ 5″; fossil ore hard 2′ 10″; clay 0′ 2″; fossil ore, hard 2′ to soft shale floor, water bearing. Dr. Frazer's analysis showed:—Iron 30.34; silica 37.99; alumina 9.56, etc. In 1873 this ore was mixed, one quarter with three quarters foreign ore, in a Pittsburgh furnace with success, as it supplied a deficiency in silica and alumina.

The Frankstown mines.

The Frankstown fossil ore bed, worked extensively near Frankstown seems to hold a regular position 400′ beneath the *Double ore bed*, but only in this particular neighborhood, beyond which it thins away. The ore where minable is so valuable that all the mountain slopes around Frankstown and Hollidaysburg have been diligently searched for it, but in vain; a flagrant illustration of the local character of this and in fact all other fossil ore deposits.

The Frankstown ore bed is overlaid by more than 40′ of fossiliferous blue slate in which occur three *ore pins*, as they are called; reddish silicious layers from ½″ to 2″ thick full of small shells; the upper, 37′, the middle, 26′, the lower, 17′ above the ore bed; which itself ranges from 8″ to 22″ in thickness. A fourth ore pin lies 4″ below the ore; and a fifth 10″ below it; but they also are of no value. The roof of the bed is a sandy fossiliferous blue slate with worthless bastard ore 2′. The floor of the bed is slate holding the two lower ore pins 10″; lying on chocolate slates 20′; lying on various shales 130′; lying on shales and probably some sandstone layers 50′; lying on the Keel or block ore bed.

The Frankstown slope mine on this bed has been worked since 1846*. The slope is 710′ long, the bottom of which is 218′ beneath the surface. The mine has sometimes yielded 20,000 tons in a year. Small downthrow faults are numerous, the largest making a throw of 16′.—A little *buried valley* was encountered at the east heading of the mine 84′ beneath the surface. A mass of loose stuff, Medina sandstone boulders, branches of trees, leaves, etc. here cut out the bed (under the miner's village), beyond which the bed resumes its place and character and is worked at the old Rocky mine 225 yards east of Roaring run. A mile east of the Rocky mine the bed is regular, with regular upper and lower measures, but only 8″ thick. Half a mile further east it was found to be only half an inch thick.

The Williamsburg Manufacturing Co. worked the bed back of Frankstown, where it presents the same features as at the Slope mine.—Two-thirds of a mile north of Hollidaysburg the Patterson mine, now worked out, found the

*Miller & McNeal; then Moore Brothers to 1849; Watson, Dennison & Co. to 1863; since then Blair I. and C. Co. a part of the Cambria I. Co.

bed parted with slates; the red bastard ore 2′ above it as at Frankstown; the gray bastard ore at the bottom of the bed with a thin slate between. The fossil shells in the gray bastard are larger than those in the beds above.—At the north line of the Patterson place the ore bed comes to an end; all efforts to find it beyond that have failed. Half a mile to the northeast on Young's place the overlying *pins* are all right and regular, but there is no ore bed. If the miners' identifications of the various members of the group can be relied on, the 17′ pin, when followed beyond the ravine northeast of Young's, rests directly on the chocolate slates, all the intervening beds with the ore bed itself having thinned to nothing; but a scrupulous field geologist will require the amplest evidence for the truth of such an explanation. Four miles further northeast of Sackett's (Bell's) place, the 17′ pin is again said to rest directly on top of the chocolate slates, cutting out the intermediate measures.

The Frankstown ore is everywhere of one character; hard and tough; deep red in color; not greatly varying in the analyses of samples. One of Mr. McCreath's analyses gave:—Peroxide of iron 59.857; peroxide of manganese 0.403; alumina 2.748; lime 12.110; magnesia 4.195; sulphuric acid 0.087; phosphoric acid 0.588; carbonic acid 14.075; water 1.305; insoluble 4.800; (iron 41.900; manganese 0.280; sulphur, 0,035; phosphorus 0.257.) His second determination gave:—Iron 40.40; insoluble residue 5.86. A Johnstown analysis gave:—Peroxide of iron 61.27; silica 6.46; alumina 1.50, etc.; (iron 47.50.)

North of McKee's gap this Frankstown bed, that is, the bed about 400′ above No. IV, has been opened near the mountain crest. South of McKee's gap the openings have been abandoned. The Martha furnace tunnel at McKee's gap commenced in red shales, and is said to have then passed through limestone beds 215′; gray slates 60′; to soft fossil ore bed 3½′. One analysis gave 52 per cent of iron, 11 per cent insoluble residue and 8 phosphoric acid. A check analysis by Mr. McCreath gave:—Iron 47.100; manganese 0.194; sulphur 0.033; phosphorus 0.174.

The Block or Keel ore bed in this Frankstown-Hollidaysburg district is nowhere worked; but has been tested at the outcrop in many places and seems to be an entirely persistent formation along the mountain; very different however, in its character from the block ore in the Huntingdon valley along Tussey mountain; at the Cambria Iron Co.'s opening it was a group of sandy layers 12′ thick; 2′ of which holds 17 per cent of iron; the remaining 10′ from 7 to 11 per cent.

South of Tyrone City gap this bed has been opened (vertical) 260′ above the river. 6½′ of rock ore, the uppermost 22″ in six layers being workable; the creep has given it a S. E. dip.

CHAPTER LXII.

No. V in Centre, Clinton and Lycoming.

The vertical dip of the measures at the Tyrone gap of the Little Juniata river through Bald Eagle mountain continues to prevail all the way to the Susquehanna river at Lock Haven in Clinton county; after which the dip gradually declines to 45° in Lycoming county. A number of old iron furnaces stand along the Bald Eagle Creek, stocked from the brown hematite mines of Nittany valley, to the south-east of the mountain, over which the ore was hauled. Expectations were entertained that sooner or later the Clinton fossil ore beds on the slope at the foot of which the furnaces stood would be found thick enough to work; but such expectations have long ago been relinquished.

Bald Eagle furnace is 5 miles from Tyrone City; Hannah furnace 10 miles, at the head of the creek near the *Blair-Centre* county line; Matilda, 14 miles; Martha, 17; Juliana, 21; Unionville is 26; Milesburg at the Bellefonte gap where Spring creek enters the Bald Eagle, 31 miles; Eagle works, at Curtin, 34; Mount Eagle, 36; Howard furnace, 40; Eagleville, 44; and Beech Creek, descending from the Allegheny mountain coalfields, and making the boundary line between Centre and Clinton county, 46; Mill Hall, where Fishing Creek breaks through the BaldEagle mountain from the south to join the Bald Eagle Creek, 51; and Lock Haven where the creek enters the Susquehanna West Branch, 54 miles.* Pine creek enters the river on the Clinton-Lycoming county line at 64 miles; Jersey Shore is at 66; Larry's creek at 68; Lycoming creek at 76; Williamsport at 78; the Loyalsock at 82; and the Muncy bend at 88 miles from Tyrone City.

*The town stands between the two streams, which meet two miles further east.

Fossil ore absent.

Along this whole line it can hardly be said that the Clinton fossil ore beds have ever been mined, or ever will be, to any notable extent.

Fractures and Faults.

It has already been said that the dip east and west of the Tyrone City gap is vertical or even overturned; and that this vertical dip is maintained for many miles to the northeast; the formations of the mountain descending from a great height in the air to the depth of a mile underground. This structure accounts satisfactorily for the amazing *straightness of the Bald Eagle mountain*, the Bald Eagle valley, and the Allegheny mountain for 50 miles, one of the most striking phenomena presented in the geology of Pennsylvania. For most of the distance this vertical wall, a mile thick, is to all appearance unbroken; although if mining operations should ever be prosecuted in it, no doubt thousands of *small fractures* and insignificant throws to the right and left would be found to exist, similar to those in the gangways in Black Log mountain at Orbisonia; to those mentioned above in the Frankstown mines; and to the up and downthrows reported in the nearly horizontal coal beds of Osceola and Phillipsburg, 10 miles distant to the northwest in Clearfield county. But it must not be supposed that these fractures are confined to this central district of Pennsylvania. They undoubtedly pervade the entire State, being more numerous however in the presence of the larger anticlinals. It is not probable that they were made at the time of the folding of the anticlinals, which took place in the general elevation out of the sea into the air of sand and mud formations so charged with water as to be in a plastic state. It is much more reasonable to suppose that they have been produced successively or in batches, so to speak, by the perennial earthquakes which have shaken Pennsylvania, and all other parts of the earth's crust, in all ages from the coal era to the present moment; and some of them have been established as lines of greater weakness and been increased from time to time by one earthquake after another until they have become larger than the rest.

The Bald Eagle mountain faults.

Two of these larger downthrows occur a few miles east of Tyrone City. They crack transversely the mountain sand-rock No. IV, the Clinton No. V, and of course whatever fossil ore beds this may contain. They throw the whole mountain westward; that is the south wall of each fracture has moved against its north wall westward. In the case of the *Vail station fault* the throw amounts to 1400′; in the case of the *Bald Eagle furnace fault*, to 1300′; but as the faulting is diagonal to the strike, the *slip along the fault* is in the first instance 1900′, and in the other 1400′. At each line of fault the Clinton formation coming from Bellefonte towards Tyrone City abuts against the Medina formation; and of course, were fossil-ore-beds to be worked in this section of the mountain, mining operations carried westward would come to an end against each fault. No ore outcrops however have as yet been found of a character to justify mining operations. *

From the appearance of the mountain between Bald Eagle Station and Lock Haven it is not probable that other faults of equal magnitude exist; but if the topographical survey of the Tyrone City end of the mountain were carried eastward toward Lock Haven and Williamsport, smaller but similar disturbances would be discovered; and in every instance Formation No. V, with any fossil ore beds it may contain, would be found broken and thrown in the same style and probably in the same direction.

Although the outcrop of No. V, along the Bald Eagle mountain gives slight promise of successful fossil-ore mining, it must be remembered that the numerous ravines which descend from notches in the unusually broken summit line of the mountain furnish poor exposures. The

* This interesting local structure is represented in detail by the contour line map in Report T3, and its effect on the topography is strikingly exhibited by the model, a photograph of which is published on page 368 of that report; the details of the faults also are minutely described. The map is reproduced on a reduced scale in Plate LXXVI, page 630 above.

slope is generally covered with a thick deposit of clay, filled with fragments of Medina sandstone, everywhere hiding from view the position of the limestone strata, ore-bearing or otherwise; and the vertical attitude of the beds forbids their conversion into soft-ore far beneath the surface. Numerous prospecting pits, sunk at various times for the furnaces, yielded fragments of very fossiliferous and calcareous layers, with buff shales; but nothing that could be called workable ore beds. In many cases the rocks were seen to dip into the mountain, suggesting at first sight little synclinal basins; but in every case the creep of the outcrops downward had thrown them over from the vertical to angles even as low as 45.*

At Port Matilda (14 miles from Tyrone City) on the foot slope of the mountain (200′ above the railroad) the calcareous shales of No. V, have a *southeast dip* of 30°; and the same reverse dip was noticed elsewhere; there must therefore be a small basin of No. V running along the foot of the mountain. The lime water from these beds incrusts the stones in the rivulets; and the numerous *paint springs* along the mountain probably issue from beds of fossil ore; although it is no proof that they are workable. The principal fossil shells are species of *Orthis*, *Atrypa*, *Strophomena*, etc. (T4, 429).

In the Milesburg gap, in front of Bellefonte, the Clinton olive shales stand nearly vertical. The local topographical map (given in Report T4, p. 281) with contour lines 100′ apart, show the sharp crest-prong of Medina white sandstone which points into the gap, from its southwest wall, towards an equally well pronounced (but only half as high) spur on its northeast wall. There can be no fracture in this gap; for the vertical crop-line across the gap is perfectly

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*This was the case in a pit three quarters of a mile northeast of Hannah furnace; where sparry-ore-limestone was found interstratified with dark olive fossiliferous shales (See section on page 553 Geol. Penn. Vol. I, 1858). The slope of the mountain is here very steep; No. VIII occupies the foot; No. VI is one-third of the way up; and the ore horizon about three-fourths of the way to the summit. The regular dip in the mountain is 85° northwest. The ore bed is 22″ thick, yielding 28 per cent iron. The bed at Howard furnace was mined for a short time and then abandoned.

straight. On the northwest slope of the first spur, in the red and buff shales (with no limestones visible) the ore bed was found after years of search, but it was not workable.

From the gap at Milesburg to the next gap at Howard, or Jacksonville, a distance of 19 miles, the mountain crest is much notched, and its Clinton slope worn and gashed, and its wooded surface hid by broken rocks in clay. At Eagle furnace, however, the slope is comparatively long and gentle; the cement layers of No. VI run along it about 200 yards from the foot; on the west side of the gap they dip 70° (N. W.). Here a synclinal trough runs along the foot of the mountain, the limestones of VI rising vertical in the low ridge next west of it, and then turning over and going down (N. W.) with 30° dip in a second ridge. The *Salina* formation appears on the anticlinal arch in the vale between the two ridges. The *Bloomsburg* (Salina lower) *red* shale belt runs along the mountain slope, and the ore bearing *Clinton shales* high up near the summit.

At Howard furnace the *ore sandstone* is represented by a few thin layers of grey grit in the shales overlying the *Fossil ore bed*, about half way up the mountain slope, hard, only 6″ to 10″ thick, dipping 80° (N. W.). The *Block ore* outcrop is about 180 feet higher up the slope; is merely an iron sandstone, 16″ thick, and holds no shells.

In Morrison's gap, or notch, near the mouth of Beech Creek the Salina rocks are as usual concealed by woods and slidden rock stuff.

At the Mill Hall gap, 5 miles southwest of Lock Haven, in Clinton county, the shales, slates and thin sandstones of No. V measure 1080′ in Dr. Chance's section (G4,129), but they are almost entirely concealed from view. The *fossil ore bed* mined here by the Mill Hall Furnace Company runs from 10″ to 12″ in thickness. The *block ore* has also been mined.

In the section made here no distinction is made between the Salina and Clinton, und the Salina strata are probably concealed in the valley of the Susquehanna river.

Mill Hall part of Lock Haven Section (*G4, p. 128*).

No. VII;	seen occasionally at intervals along the valley.		
No. VI.	Limestone massive, impure, shaly on top,	80′	370′
	Lime shale and impure limestone, . . .	83′	
	Soft, dark, bluish black slates, upper part calcareous, ...	177′	
	Limestone, shaly and massive, . . .	30′	
	Concealed Interval (Salina?), ...		500′+
No. V.	Limestone, massive, quarried, . . .	25	1105′
	Shales, slates and thin sandstones, . .	1080′	
No. IV.	Medina white, gray, and red sandstones.		

A mile and a half west of Mill Hall and a mile from the mountain the cement layers of VI are quarried. A third of a mile southwest of this the canal has exposed a series of limestone beds, dark, yellow, massive, fossiliferous, fetid, etc., dipping 35° (N. W.) for 300 yards; under which lie Salina ash-colored lime shales, fossiliferous.*

The Bloomsburg red shale makes the mountain slope; and east of the gap the Clinton lime shale beds are quarried for lime burning 200′ above the creek.

In Fleming's gap (two miles west of the mouth of Bald Eagle creek) the Clinton olive slates dip only 30° (N. W.); and half a mile west of the creek mouth, the Clinton ore limestones are quarried, dark in color, and showing alternations of calc spar and slate, with corals and shells, dipping 35° (N. W) close to the foot of the mountain, which is here at its best height and continuous.

From Lock Haven for 7 miles east the Salina division of No. V is covered either by the water of the Susquehanna or by the mud-flats which it has deposited; † while the Clinton division makes the mountain slope.

On Pine creek near Jersey shore fine exposures of No. VII and VI appear, coming up and going down in anticlinal waves; ‡ the northwest dips of which are vertical, the southeast dips 40° and 50°. The first ridge on the creek just above its mouth has a crest of No. VII, a slope of No. VI, and a valley foot along the river of Salina No. V. It

* See section in Chapter on No. VI. (Geo. Pa. 1858. I. 545.)

† It is a flat $6\frac{1}{2}$ miles long and 2 miles wide, in which the river makes its great bend at Chatham's run.

‡ Geol. Pa. I, 544; section. See description in the chapter on No. VI on a future page.

curiously resembles the Steinberg (Stone ridge) behind the Lehigh Water Gap in all particulars. The second ridge up the creek is a repetition of the first. Between them lies a vale of No. V brought up on the back of the anticlinal, and strangely crumpled and contorted by the pressure. Some of the lime shales have been dissolved so as to produce a *cave*, 3′ high at its mouth, 15′ to 20′ high inside, and extending nearly a hundred feet into the hill.

At Jersey Shore we are in Lycoming county. The river cuts into the Clinton rocks of the mountain slope above and below the mouth of Pine creek; and then suddenly leaves it where Nippenose creek issues from the Gap and flows across the Jersey Shore flats in a great bend (in front of the gap) to return to the mountain again two miles further east. About 400 yards above the mouth of Nippenose creek are long rock exposures of *Salina variegated shales*, dipping 35° (N. W.). Under them the *Bloomsburg red beds* are exposed for 100 yards. Under these are limeshales and contorted layers of limestone, from 4″ to 36″ thick, traversed by veins of calc spar, and speckled and roughened on the weathered surfaces with multitudes of minute discs of broken-up stems of *stone lilies* (*encrini*) black on a ground of lead color. These *encrinal beds* are exposed for 50 yards along the river bank, and alternate with dark olive or blackish slate in the lower part of the exposure. Under these come alternations of blackish slates with reddish and dark brown thin shales, the layers falling away in squarish plates. Under these appear green slates; and then yellowish shales—opposite Pine creek mouth.

In all this long and clean exposure there is not a sign of the fossil ore beds.

The Encrinal beds are of great importance to the field geologist; for, as the fossils have been torn to pieces and their little dises carried far and wide by water currents, this horizon should be a very extensive one, and serve as a base of measurement for the identification of other beds over the whole region.

At the sharp bend which cuts into the mountain 4 miles east of Jersey Shore the following section is exposed (Geol. Pa. I, 543):

Section East of Jersey Shore.

Salina lower (*Bloomsburg*) *red shale;* dip 35° (N. W.).
Olive shales of considerable thickness.
Limestone strata, granular, massive, with *very fossiliferous* slate strata between.
Shale, dark, loose, *very fossiliferous.*
Limestone strata *full of fossils.* Inside pure; outside surfaces turned to *good ore.*
Olive shales.
Limestone strata *full of trilobites, shells, corals, encrinal discs;* two of these beds have enough iron to make them a *hard ore.*
Buff shales, *very fossiliferous.*
Olive shales, thin strata.
Reddish strata, some of them compact.
Olive shales; holding thin layers of dark sandrock breaking into rhombic pieces, and containing *some white shells, and multitudes of some obscure seaweed* (*fucoid*).*
Slate, brownish, laminated (50′±); *no fossils.*
Olive slate, covered with soil. Dip 35° (N. W.).

No distinction of *Salina and Clinton* can be made in this section. There are in it *four* limestone beds with enough iron in them to justify the name of *hard fossil ore;* but they are only used for building purposes and lime burning. This 'fossiliferous series is exposed by the creek at the limekiln in Nippenose gap; at the mouth of which the olive and red shales run low on the mountain slope.

In the Musquito gap opposite Newberry, in Hagerman's run gap opposite Williamsport, and in the ravine gap opposite the mouth of Loyalsock creek, the *Clinton and Salina* strata do not show themselvss. The overlying *cement layers of No. VI* are also concealed beneath the river flats from Pine creek to beyond Williamsport; but thence onward, west and east of the Loyalsock there are fine natural exposures and extensive quarries of them, dipping

*A mile further west No. IV is uncovered (45° dip), and near by are overlying beds full of *fucoids.*

30° to 35° (N.). At the quarry on the road 3½ miles east of the Loyalsock, the *cement layers* are seen overlying *Salina Variegated shales* in the ravine and these overlying *Bloomsburg red beds* at the canal lock; these are also exposed along the canal. Six miles east of the Loyalsock the river begins its great bend past Muncy around the dying anticlinal of the Bald Eagle mountain, cutting twice through formation No. V, both on its north and on its south dips, and nearly to its base. Muncy creek (from the east) enters the river at the apex of the bend, the anticlinal axis being seen in the creek 600 yards from the river. Carpenter's run (from the north) enters the river through Limestone ridge at the north corner of the bend.

At the Muncy bend of the West Branch of the Susquehanna river in eastern Lycoming county one of the best studies of No. V was made by the geologists of the First Survey; † and the results obtained by compiling local exposures in a general section (which has however almost as much value as a local section) are given by Prof. Rogers in his Geol. Penna. 1858, Vol. 1, p. 535, as follows:

Muncy section of No. V.

No. VII, Oriskany sandstone, usually thin and in some places absent,		—
Dusky shales, weathering buff; upper beds sandy and *cherty*,		60′
No. VI, Limestone, corals and numerous other fossils; lower beds encrinal, . . say		150′
No. V, Salina limestone, thin bedded, blue with *Cytherina alta*,		100′
Gray marls (Moore's quarry above Lewisburg),	300′?	
Blue shales and thin limestones and thicker black fissile slates (Shoemaker's Mill, Muncy creek), visible,	200′	
Gray, greenish and bluish marls and some purple and blue slates, some clay lime flags (some beds of which are 20′ or 30′ thick),	?	
Shales, *blood spotted*, (west bank, 1 mile below Milton),	1100′	=1600′
Red and green shales at Muncy bridge	20′	
Bloomsburg red shale,	350′	=370′

† This district was given to Mr. Alex. McKinley.

Clinton Upper lime-shales gray and green, . . .	40′
Limestone with *Beyrichia, Calamopora, Atrypa, Cytherina, Avicula*, etc., ...	65′
Greenish and buff slates, . .	65′
Alternate slates and fossiliferous limestone beds (4″ to 24″) containing four or five poor fossil ore beds,	60′=230′
Clinton Lower lime shales (5 miles below Jersey Shore) greenish with sandy limestone layers holding the trilobite *Agnostis hemicripterus* and a small branching sea weed (*fucoid*), ...	110′
Clinton slates, with branching fucoids; holding somewhere *iron sandstone* which contains an ore bed,	700′

The Salina (?) limestone with *Cytherina alta* is a key rock along the whole West Branch valley and can be everywhere recognized as distinct from the overlying excessively fossiliferous limestone beds of No. VI by its being almost entirely destitute of corals and encrini. Its lower layers are argillaceous and magnesian and therefore fit for hydraulic cement. For this reason however it should probably be classified as the lowest division of No. VI. Between Muncy and Jersey Shore it measures from 40′ to 60′, but at Milton and Lewisburg at least 100′; and as it increases in thickness it holds more and more chert or flint balls. In Blair and Bedford counties it becomes more than 200′, and on the Potomac 250′.

The Salina Upper and Middle marls are given in this section a thickness of 1600′ and divided into four groups. But where exposed at Muncy creek with thin black clay limestones and fissile slates they only measure 1000′. Some of these clay limestone layers are of considerable size, and many of them in the lower part of the mass are sufficiently magnesian to make hydraulic cement; the cement quarries on the Potomac are in this lower portion. The only fossils noticable are the extremely common Clinton forms *Cytherina alta* and *Beyrichia seminalis*. The palæontologist would therefore consider the Salina and Clinton sub-divisions of No. V here as all one, and take it as a proof that the intermediate Niagara formation must be entirely absent; or, considering the whole as Clinton, would look for the Niagara at the extreme top of the mass, and consider the Salina to be absent. A field geologist however must recognize the distinction throughout this region between Salina and Clinton and consider the Niagara as absent.

The red and green shales at Muncy bridge (20′) are merely a passage downward from Middle to Lower Salina.

The Bloomsburg red shale, here given at 350′ of thickness, resembles the deposit in other counties. Its beds of sandy clay marl contain almost no fossil shells; are usually of a dull brick red color; and some of them are calcareous enough to be considered limestones. The group appears to grow more sandy toward the Juniata; and cannot be recognized on the Potomac.

The Clinton Upper shale is subdivided by Prof. Rogers into four. The uppermost beds (40′) of gray green shale contain some of the fossil species of the next underlying subdivision. This is a group of clay-limestone beds (60′ or 65′) with thin shale partings; its characteristic fossil *Beyrichia seminalis;* but *Cytherina alta*, *Atrypa lacunosa*, *Calamopora*, *etc.*, very abundant. These fossils ally the group with the 15′ limestone at Danville. Next underneath lie greenish and buff colored slates (65′) with some of the same fossil species. The lowest of the four groups, fissile green shales (60′) contain eight or ten thin layers of fossiliferous ferruginous limestone, four or five of which are often nearly rich enough to be called *hard ore beds*. They vary in thickness from 4″ to 24″; but the richer layers of ore are only 4″ thick.

The Clinton Lower lime shales also contain true limestone beds abounding in *Beyrichia hemicripterus* and other characteristic Clinton shells. It yields also a small branching sea weed *Buthotrephis gracilis.*

The Clinton bottom slate formation, not less than 700′ thick, is divisible into upper and lower by the Iron Sandstone; the place of which however, is not well determined. The slates are fissile, greenish yellow, weathering brown and chocolate red. They seem to be less sandy along the Bald Eagle mountain than along Montour's ridge, while their total thickness is the same, or perhaps a little less. *Buthotrephis gracilis* is only seen in the slates above the Iron sandstone.

The Iron Sandstone seems to be a persistent formation; but this fact cannot be absolutely demonstrated; there may be more than one horizon; which would account for the uncertainty of its place in the section. It has only been discovered here and there along the range, high on the mountain slope, owing to the general steep dip. Large fragments of it are seen in the bend of the Susquehanna a few miles below Jersey Shore.

At the mouth of Muncy Creek its channel is cut in Clinton ore-shale series exposed (dips slightly to the east) on the creek and in the river banks north and south of it; the *olive shales* underneath; and the *lime shales* over them. Going up the creek the overlaying (Bloomsburg) *red shales* occupy the banks and are exposed east of the bridge a mile from Muncy. Then descend Salina *variegated shales;* then for 50 yards still higher up the creek the *Cement layers* or buff limestones dip 25° (E.). the series resembles that exposed by the river at Lewisburg in Union County.

The Clinton olive shales dip 30° (N.) up the river from Muncy Creek mouth, and pass under water level. Their *massive, curved* and *twisted limestone layers, full of shells* and *encrinal fragments and quarry veins*, quarried and polished for mantel pieces, elegantly exhibiting sections of the embedded fossils,—alternating with beds of slate in the lower part,—form low cliffs at the mouth of Carpenter's run. Ascending the run the *Bloomsburg (Salina) red shales* line its banks.

At the end of Limestone ridge is a large quarry on the N. dip; and other quarries along the outcrop westward; but the Clinton is covered by the river gravel for some miles westward toward the Loyalsock. The thick and curved *enclinal limestone* beds appear again 4½ m. E. of the Loyalsock, separated by thin slate partings, and veined with spar. (From this westward has been already described in the preceding pages.)

Chapter LXIII.

No. V in Union, Snyder and Northumberland.

The only district in the state where a solid block of country is occupied by No. V is the district traversed by the West Branch of the Susquehanna river, after leaving Muncy and flowing south to meet the east branch at Sunbury. Between the mouth of Spring creek and the end of Montour's ridge, a distance of 16 miles, the river flows across Clinton and Salina rocks, rising and falling in a series of anticlinal and synclinal axes which issue from the projecting spurs of the Buffalo mountains to the west. The deepest of the synclinals at Lewisburg makes an exception to this statement; for, the river here, that is, for two miles or more north of Lewisburg, cuts through No. VI and VII and the lower part of VIII; but with this exception the whole country for miles back from the river in Northampton and Montour counties eastward and in Union and Snyder counties westward is a vast farm under high cultivation. Its great fertility is due to the innumerable calcareous layers, limestones and lime shales of the Salina and Upper Clinton series the outcrops of which zigzag across the rolling plain in a way to baffle description except by reference to a geological map. See the sketch map on Pl. CXXV, B, further on, showing by dotted lines the lowest limit of the Clinton next the mountain, and the uppermost limit of the Salina next the limestone ridges of No. VI and VII. The map shows also the outcrop belt of the *Bloomsburg red shale* (*Salina Lower*) intermediate between these lines; and in this way the general distribution of the Clinton and the Salina throughout the district can be understood without verbal description The Geological State Map of 1841 (published in 1858) was so defective in this district that a special survey was made of the outcrop belt of Bloomsburg red shale in 1877, and the results of that survey not otherwise published were embodied in the colored map of Union and Snyder counties. See the Hand Atlas, Report X, plate 54, and the map of Northumberland and Montour, plate 44.

Between the Bald Eagle mountain ending at Muncy and the White Deer mountain ending at Spring creek 10 miles lower down the river, lies the triangular valley of White Deer Hole. bounded by Spring Creek and filled with the broad outcrop of No. V, except on the river where the Muncy hills of VIII cross from the east and point out a few miles on the wast.

South of White Deer mountain the whole country west of the river is called in general terms the Buffale Valley, although it is in fact a great rolling plain. The mountain spurs recede more and more from the river going southward to Penn's creek and are named in the following order:—1, White Deer mountain; 2, Nittany mountain; 3, Buffalo mountain; 4, Mifflinsburg mountain; 5, Hartleton mountain; 6, Paddy's mountain; 7, White mountain; then, 8, Jack's mountain, which runs out far beyond the others eastward, and ends where the Snyder county line strikes Pine creek, a mile from Centreville.*

Around the end of Jack's mountain the southern outcrop of No. V passes and runs west into the Lewistown valley on the middle Juniata which has been already described. Sufficient reference has also been made to the mines along this

*The *Nittany axis* leaves the mountain spur, 4 miles from the river, the dips on the river being 15° (N. and S.).—*The Buffalo spur* is 6 miles from the river; its axis crosses tbe river at New Columbia.—*The Mifflinburg spur* is 10 miles from the river, which its axis croses a few hundred yards north of Milton bridge.—*The Hartleyton spur* is 14 miles from the river, its axis makes a beautiful exposure of gently arching strata in Penn's creek below the old Brooks' sawmill. The mountain is broken by five gaps.—*Paddy's or Path Valley axis* well exposed in Laurel Run gap with N. and S. dips of 10°; on Spruce run 2 miles west, and Buffalo creek (Breyfeyle's sawmill) 2 miles east of of Hartleyton; at Orwig's mill; on East Buffalo creek, 1 mile above Rocky's mill; on North Buffalo creek; and near the mouth of Rapid run (60° S. dip; gentle N. dip) 2 miles north of Mifflinburg its ore group dips 45° (S.) and the outcrop crosses the river below Lewisburg. From Young's tavern to Rangler's mill, the rocks are much disturbed; at the tavern *vertical*; at the mill 15° (S.).—*White mountain Knob* axis runs east passing just north of Mifflinsburg; crossing Penn's creek below tbe Deep Hollow, where the north dips rise to 60°. The synclinal south of it crosses Pine creek below Miller's sawmill with dips of 20° (S.) and 90° (N.).

southern outcrop from Winfield and Turtleville on the river past New Berlin and Centreville on Pine creek to Troxlerville and so on to Lewistown.

The fossil ore beds of the Upper Clinton, outcrop in zigzags in front of the mountain spurs and up the intervening valleys ; and have been proved by innumerable pits to exist occasionally of workable size but generally thin ; always with soft ore at the surface, becoming hard limestone fossil beds underground. Mining operations, however, have as yet been confined exclusively to the southern or Jack's mountain range, which crosses the Susquehanna river and keeps on eastward to Danville and Bloomsburg where it has been described in a previous chapter.

The Upper Clinton rocks cross the river into Northumberland in only two places, first around Watsontown and second about two miles north of Milton, the strata being exhibited along the river bank and railroad cuttings.

The Bloomsburg red shale belt crosses the river at the mouth of Delaware run and makes a loop around Watsontown returning to the river just north of Warrior run. It re-enters Northumberland county south of Warrior run and sinks at McEwensville and again on the north bank of Muddy run. Another belt of the Bloomsburg crosses the river at the mouth of Muddy run, runs east for 3 miles and returns to the river at Milton. All the space between these four loops of Bloomsburg red shale and the grand loop made by No. VI in Northumberland county is occupied by Salina outcrops.

The exposures at Lewisburg on the north dips of the great synclinal begin with the horizontal black slates of No. VIII, half a mile north of the town, where Dale's hill comes to the river. The hill is made by the hard limestones of No. VI, and its surface is strewed with fragments of Oriskany sandstone No. VII, full of the holes left by the dissolution of the large fossil shells of that formation. Under the massive limestone strata of No. VI rises the thin bedded clay limestones and clay shales of the *Salina upper group*, some of the beds being preferred by lime burners to the beds of No. VI, which are often too full of chert balls produced by the sponge fossils.*

A mile south of Lewisburg the *Salina lower* (*Bloomsburg*) red shale series comes up to the surface (400 yards south of Turtle creek); its calcareous layers dipping 20° (N.).—Then 200 yards further south three *Clinton fossil ore beds* appear, each only 4 inches thick, and too wide apart to permit of mining them together. They are full of fossils. † The limestones of this ore series are quarried, a mile below Lewisburg, a few hundred feet from the river.‡

From below the ore series come up the *Clinton middle shales* on the anticlinal of Montour's ridge which crosses the river at Turtleville. But to see still lower strata one must go to the end of White Deer mountain, south of Uniontown, where the Medina No. IV white and grey sandstones (with deep red flaggy clay sandstone alternations) are exposed by the river, dipping gently (7° to 10°) both ways (N. and S.), the south dips increasing down stream to 60°, and overlaid by the *Clinton lower sandy slates*, a very

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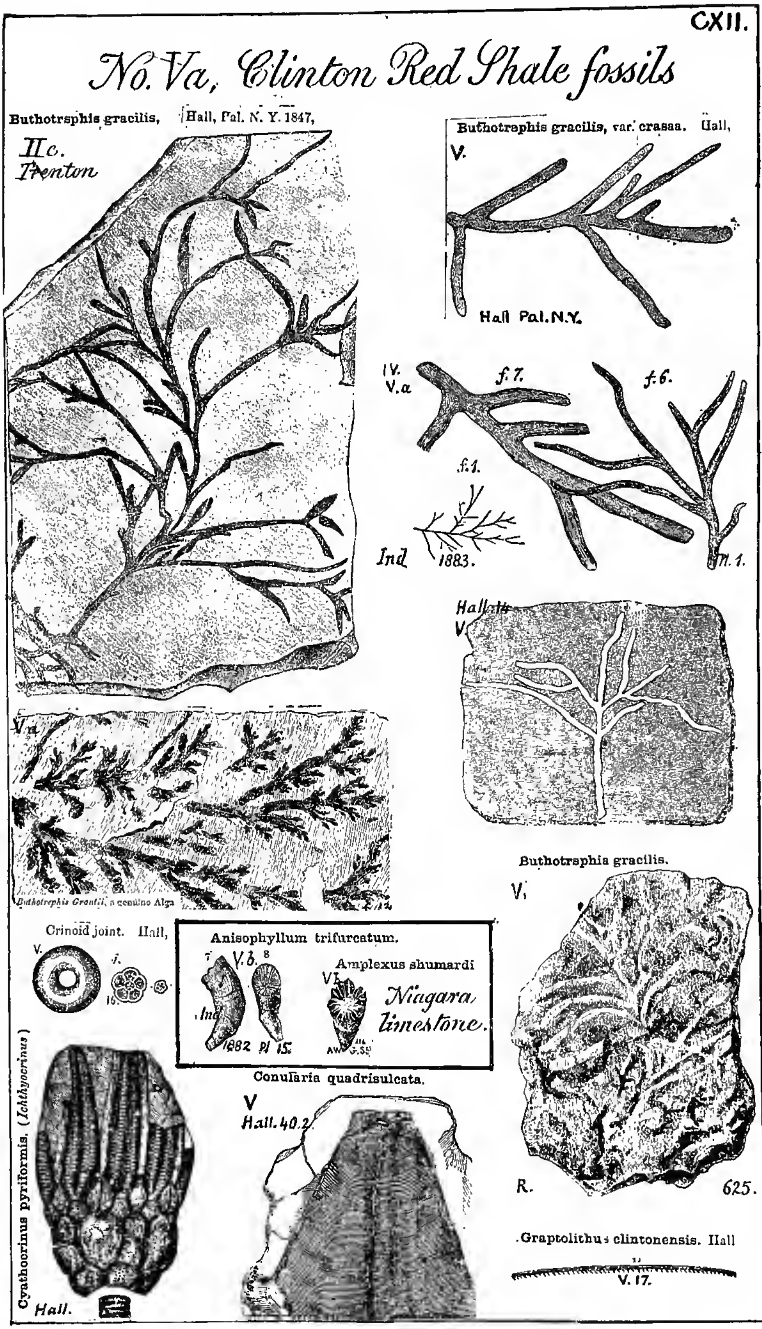
* At the quarries 1½ miles south of Milton. the *chert* is so abundant in some of the beds that they cannot be burnt at all. The quarries on the Milton outcrop are very numerous. At several of them the clay-limestones contain seams of *iron pyrites* half an inch thick; and lumps of *brown hematite iron* ore are abundant in the soil; and also fragments of brown sandy iron ore; but no valuable deposits of ore exist. Large masses of *brown brown hematite ore* have been found in the soil on the south side of Dale's hill, 4 miles west of Lewisburg. Similar quarries are opened along the Longstown ridge a gentle synclinal basin of No. VI which runs past Mifflinsburg and ends four miles west of the river.

Lead ore also has been found in the sparry seams which traverse these strata; but it is of no account. (G. P. I. 460).

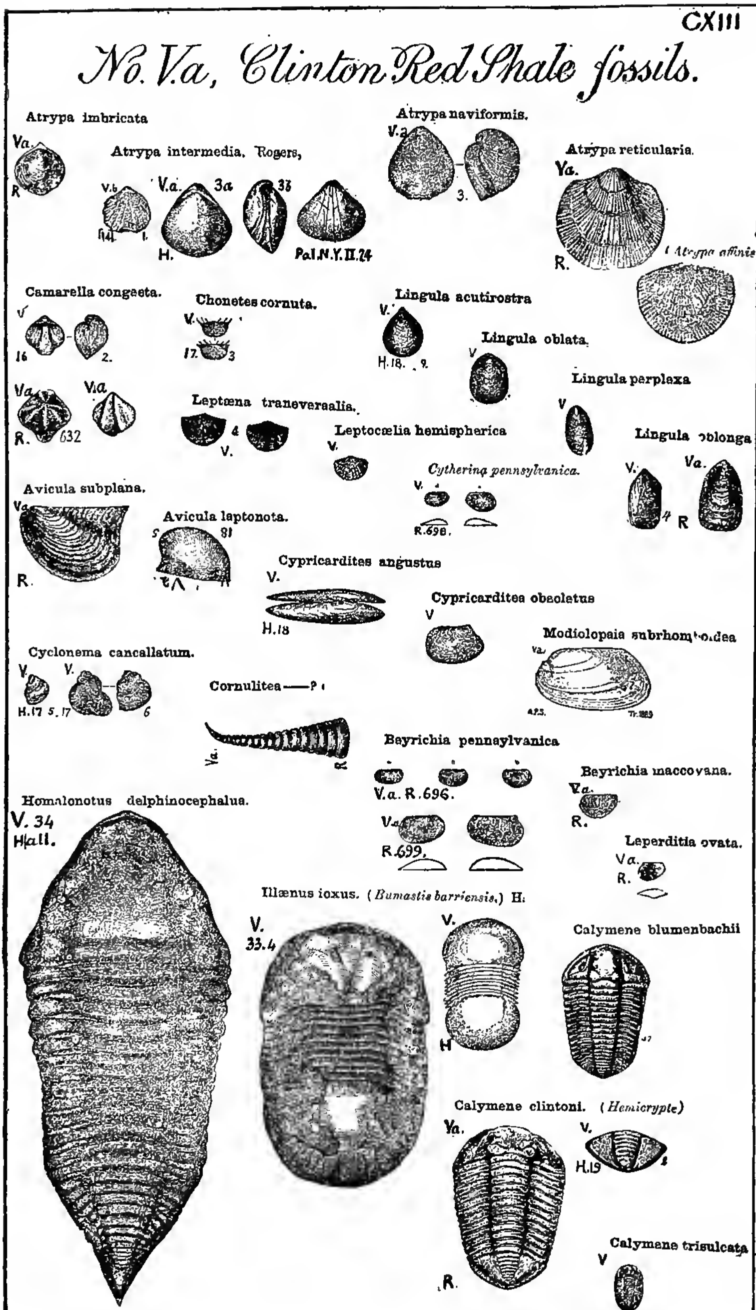
† Four miles west of the river at New Columbia and on the Buffalo mountain anticlinal, a 12 inch bed was once opened, nearly horizontal and therefore turned into excellent soft ore.—Further north an excellent 12 inch bed, in pure limestone, dips 30° (S.). (See other notices in G. P. I. 459).

‡ They are also quarried in several low anticlinal ridges which rise from beneath the Red shale series, two miles north of Mifflinsburg; the width of the group of ridges being about half a mile. The same limstones appear along the next anticlinal crests; and again on the anticlinal ridge 2½ miles west of Mifflinsburg, running south of Hartleyton. They show themselves on Penn's creek at the old Peter Miller sawmill; and they are fully exposed in the deep hollow, six miles west of Hartleytown, where they made excellent lime. In fact there is no end to the possible number of lime quarries which might be operated in front of the mountains on all the anticlinal and synclinal zigzags of the outcrop of these strata.


CXII.
No. Va, Clinton Red Shale fossils
Buthotrsphis gracilis, Hall, Pal. N. Y. 1847,
IIc.
Trenton
Buthotraphis gracilis, var. crassa. Hall,
V.
Hall Pal. N.Y.
IV.
V. a
f. 7.
f. 6.
f. 1.
Ind
1883.
Va
Buthotrephis Grantii, a genuine Alga
Hall
V
Buthotrsphia gracilis.
V.
R.
625.
Crinoid joint. Hall,
V.
Anisophyllum trifurcatum.
V. b.
Amplexus shumardi
V.
Niagara limestone.
Ind
1882 Pl 15.
Conularia quadrisulcata.
V
Hall. 40.2
Cyathocrinus pyriformis. (Ichthyocrinus)
Hall.
Graptolithus clintonensis. Hall
V. 17.

thick mass, growing gradually more of the nature of clay shale, and assuming the characteristic *buff color*. Over this mass lies another of *very fossiliferous, ash colored*, equally thick, dipping 25° (S.); becoming upwards olive colored with a pencil-shaped fracture, and finally limy, as we ascend to the overlying *Ore shale series;* over which lie the Salina (Bloomsburg) reds; and then, at the old Caldwell mill, in the south bank of White Deer creek, the clay-lime quarry beds, dipping 45° (S.).

The same series may be studied along the river above, past Uniontown, towards Muncy, on the *north dips* into the great synclinal of *White Deer Hole valley*. Here on the top rocks of No. IV lies the great mass of *Clinton slates*, in which the iron sandstone exists, for fragments of block ore follow the outcrop belt into and around the valley along a range of low hills at the foot of the mountains. Over these the ore series and lime shales make a concentric belt. The belt of Lower Salina red shale is well exposed by the river at the mouth of White Deer creek. (It is also cut by the ravines descending from Bald Eagle mountain on the opposite or southern dip, as at Hunter's mill.) The middle and upper Salina follow; and then the limestones of No. VI begin about ¾ mile above Uniontown, massive and pure and full of encrini and shells in the lower part; more sandy in the upper layers; gradually passing into the lime sandstone of No. VII, full of the casts of great shells, admirably exposed on the east bank of the river, dipping 20° (N. 5° to 10° W.). Above these rocks lie the dark shales, etc., of No. VIII in the synclinal, which descending east ward received still higher strata of No. VIII in the Muncy hill range of Northumberland and Montour counties.


CXIII
No. V.a, Clinton Red Shale fossils.
Atrypa imbricata
Atrypa intermedia. Rogers,
Atrypa naviformis.
Atrypa reticularis.
Pal.N.Y.II.24
Camarella congesta.
Chonetes cornuta.
Lingula acutirostra
Lingula oblata.
Lingula perplexa
Leptæna transversalis.
Leptocœlia hemispherica
Lingula oblonga
Cytherina pennsylvanica.
Avicula subplana.
Avicula leptonota.
Cypricardites angustus
Cypricardites obsoletus
Modiolopsis subrhomboidea
Cyclonema cancellatum.
Cornulites
Beyrichia pennsylvanica
Beyrichia maccoyana.
Homalonotus delphinocephalus.
V. 34
Hall.
Leperditia ovata.
Illænus ioxus. (Bumastis barriensis.) H.
Calymene blumenbachii
Calymene clintoni. (Hemicrypte)
Calymene trisulcata

CHAPTER XLIV.

The fossils of No. V.

The Clinton fossils most characteristic of it are *Ichnophycus tridactylus*, *Graptolithus clintonensis*, *Helopora fragilis*, *Athyris naviformis*, *Leptocoelia hemispherica*, *Triplesia congesta*, *Cyclonema cancellatum*, and *Cornulites distans*. But where the Clinton graduates upward into the Niagara, we find in the Clinton *Pentamerus oblongus*, *Spirifera radiata*, *Meristella cylindrica* and *Lingulella lamellata*, which are accredited to the Niagara.*

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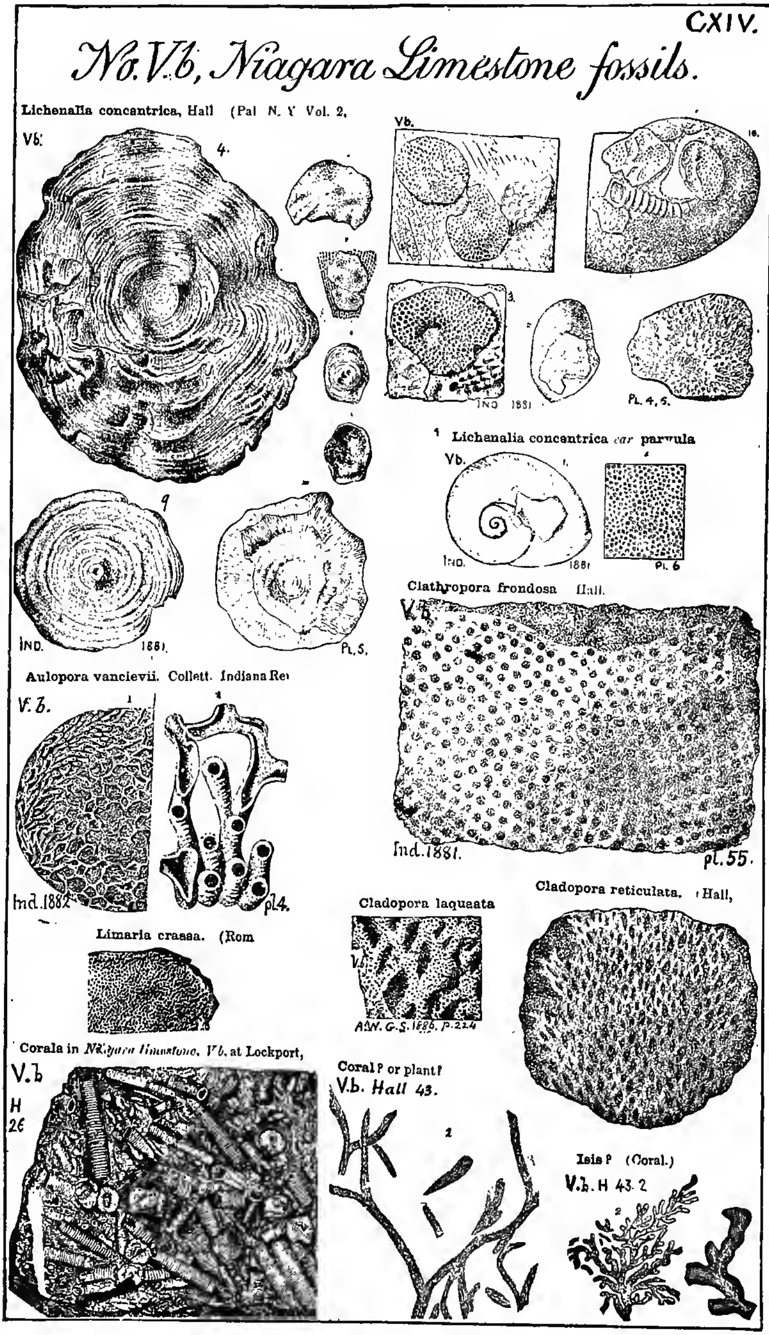
*S. A. Miller, N. A. Geol. and Pal. 1889, p. 50. In the typical locality, Clinton Co., N. Y., the formation consists of green and black-blue shale, green, grey and red sandstone often laminated, limy sandstone, and red fossil iron ore beds. At other places it consists of variously colored shales and sands, impure limestones, conglomerates and oölitic ore beds. Its outcrop in New York begins near Canajoharie on the Mohawk and runs west past Hamilton in Canada to the Manatoulin islands of Lake Huron, and thins out east of Green bay in Michigan. Its thickest in New York is about 400′. Its top limestones are now included in the Niagara. It is recognized on Anticosti island in the Bay of St. Lawrence. In Central New York there is no distinct bottom to the formation as it seems to grade downwards into the Medina. The sea weeds of the Medina continued to prevail in the Clinton age, and more abundantly than ever before. Tracks and trails of animals are also very common. Land plants are unknown.

It has been known for many years that the Clinton "fossil ore" was a replacement of the carbonate of lime of the shells of small mollusks by peroxide of iron, and that this chemical change took place only to a certain depth from the surface, a depth varying according to the facilities afforded for the percolation of the rainfall downward.

But some of the Clinton ore beds do not exhibit shells. They have however a peculiar structure called *oölitic*, suggesting a petrified mass of fish roe. The small grains of iron oxide were supposed to be concretions about minute objects, like the grains of the Green Sand Marl. Recently they have been subjected by A. F. Foerste to microscopic examination (Amer. Jour. Sci. Jan. 1891, p. 28) and prove to be water-worn rounded fragments of *bryozoa* of various species; not perfect spheres, but varying in shape and size according to the shapes and sizes of the animal fragments out of which they were made. In some cases the *bryozoon* itself has been changed to ore, and the calcareous (calcite) crystalline filling of its pores only partially changed to ore, sliced sections under the microscope making a beautiful ap-


CXIV.
No. V.b, Niagara Limestone fossils.
Lichenalia concentrica, Hall (Pal N. Y Vol. 2,
Vb.
4.
Vb.
3.
IND 1881
PL. 4, 5.
Lichenalia concentrica var parvula
Vb.
IND. 1881
Pl. 6
9
IND. 1881.
Pl. 5.
Clathropora frondosa Hall.
V.b.
Ind. 1881.
pl. 55.
Aulopora vancievii. Collett. Indiana Re
V. b.
Ind. 1882
pl. 4.
Cladopora laqueata
A.W. G.S. 1886, p. 224
Cladopora reticulata, Hall,
Limaria crassa. (Rom
Corals in Niagara limestone, V b. at Lockport,
V.b
H
26
Coral? or plant?
V.b. Hall 43.
Isis? (Coral.)
V.b. H 43. 2

Fossils of the Niagara Vb.

The Niagara fossils of New York are very numerous as described and figured by Hall and other American palæontologists. Some of these appear in Pennsylvania, but mixed with the preceding Clinton or the succeeding Salina forms. The Massive Niagara limestone beds are unknown in Pennsylvania except upon the Delaware river at Port Jervis in Pike county. At Barree on the Juniata in Huntingdon county there are some limestone beds which hold an intermediate position between the Clinton and Salina; but usually there is so gradual a passage of the Clinton into the Salina as to shut out the Niagara formation which makes so grand an exhibition of itself in Western Canada.*

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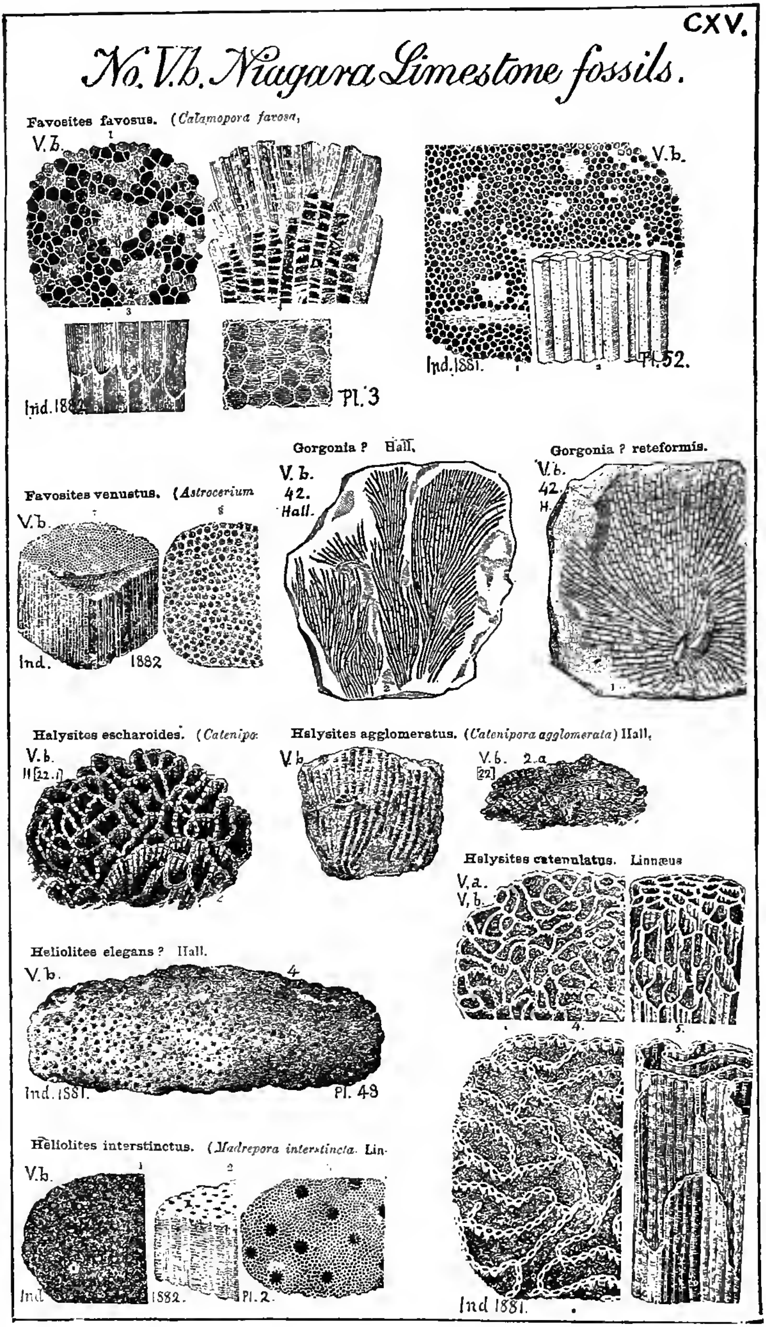
pearance. In other cases, especially in species of *bryozoa* of open growth, or with large cells, the lime cement has been wholly changed to iron ore, but the animal structure itself has been only changed to calcite, and the second change to iron ore has hardly begun; the original organic constiuthe remains quite visible; as in a specimen collected by Dr. T. W. Harris, at the outcrop two miles north of Rochester, New York; and in specimens from near Northumberland, Pennsylvania; from Wildwood Station, Georgia and from Todd's fork, north of Wilmington, Ohio. But where the calcite is completely replaced by iron ore no trace of the animal structure remains; but also there is no trace of *concretion* of iron ore, around fragments, or independently. The branching forms of *bryozoa* are most largely represented. The most common are those having cells arranging in a radiatory manner around an imaginary axis. Bilateral forms (*Ptilodictydæ* and *Stictoporidæ*) are also represented, probably all of them good *Clinton* species.

*The name was given to it by Jas. Hall, at his first study of it at Niagara Falls. Vanuxem also described it in 1842. Its northern outcrop runs the length of New York state, with a maximum thickness of 300′. At Niagara Falls it forms a ledge of solid limestone strata 85′ thick, undermined by 80′ of shale. It makes mountains on Lake Huron and the high rugged Manatoulin and Drummond Islands; spreads through Wisconsin and northern Illinois, and runs through Iowa below Dubuque, as a magnesian limestone. At Joliet it is good building stone. At Chicago it shows petroleum; in Iron Ridge, Wisconsin, concretionary hematite. In Illinois it gets up to 640′, in Wisconsin 800′, Iowa 600′. In Eastern Canada, New Brunswick, Anticosti, Newfoundland, its maximum thickness is 800′. It is recognized in Tennessee and Alabama, where its iron ore beds are sometimes 60′ thick. It surrounds the Blue Grass country of Kentucky, where its beds sum up 600′. It surrounds an uplift in south Missouri; and is recognized in the Rocky mounttains; and in the Arctic regions of British America. It seems to be the Wenlock formation of England, and is recognized in Northern, Central and Eastern Europe. Its fossils from Waldron, Indiana, are found on the Island of Gottland in the Baltic sea. The waters of Niagara age must have swarmed with invertebrate animal life. S. A. Miller, N. A. Geol. and Pal. 1889, p. 51.


CXV.
No. V.b. Niagara Limestone fossils.
Favosites favosus. (Calamopora favosa,
V.b.
Ind. 1882
Pl. 3
V.b.
Ind. 1881.
Pl. 52.
Gorgonia ? Hall.
V.b.
42.
Hall.
Gorgonia ? reteformis.
V.b.
42.
H.
Favosites venustus. (Astrocerium
V.b.
Ind. 1882
Halysites escharoides. (Catenipo-
V.b.
H [22.1]
Halysites agglomeratus. (Catenipora agglomerata) Hall.
V.b
V.b. 2.a
[22]
Halysites catenulatus. Linnæus
V.a.
V.b.
Heliolites elegans ? Hall.
V.b.
Ind. 1881.
Pl. 48
Ind 1881.
Heliolites interstinctus. (Madrepora interstincta. Lin-
V.b.
Ind
1882.
Pl. 2.

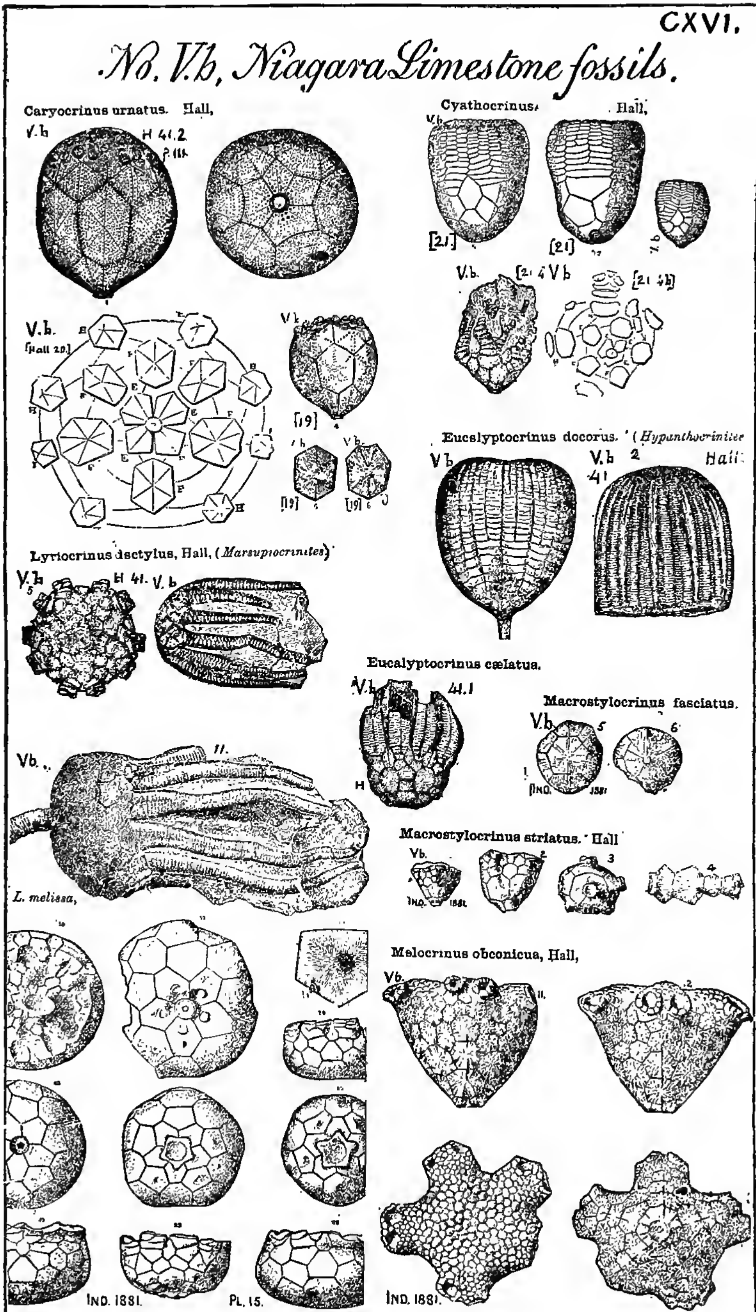
Dawson found what he considered the *earliest remains of land plants* in the Niagara rocks of Canada, *Psilophyton princeps*, a marsh plant, and *Glyptodendron*, a dry land plant. It is remarkable that seaweeds, so abundant in the previous Clinton age, are rarely seen in Niagara rocks. Sponges however were extraordinarily numerous. Corals were so common as to form reefs, traceable for miles in length along the present outcrops, masses being found several feet in diameter and of unsurpassed beauty. The species of corals were also world wide in their distribution, such as, *Halysites catenulatus*,* *Heliolites pyriformis*, *Favosites forbesii*. Echenoderms were also abundant. Cystids, which commenced long before (*Eocystites* of Cambrian times), reached their climax in Niagara waters and then suddenly disappeared from the planet, a few small species only remaining alive in the Lower Helderberg and Lower Devonian waters; some of the cystids being stone lillies without a foot stalk and therefore free floating; their mouths being in some species on top and in others near the base; some species having arms.†

The Blastoidea now first appear, in the genus *Stephanocrinus*, and continue into Carboniferous times. The Crinoidea developed fifteen genera, eight of which perished be-

*One of the best localities for studying the remains of a great Silurian coral reef is at the northern end of Lake Huron. Great Manatoulin island is sheeted in many places with a loose layer of complete and fragmentary silicified corals which have fallen out of the hard magnesian limestone strata as these have been dissolved away by the weather.

Here can be collected any number of the specimens of *Favosites, Halycites, Heliolites, Alveolites, Coenites, Syringopora, Strombodes, Cyathophyllum, Zaphrentis, Omphyma*, etc. many species of which are the same here as in the European Silurian rocks, showing the vast extent of the food-carrying ocean-currents of that day. Among them were found, in 1879, some *Favosites* with a structure different enough to justify the establishment of a new genus and species *Syringolites huronensis*, by Mr. G. J. Hinde, whose drawings of it show the growth of the coral. Landmark's *Favosites* is the same as Goldfuss' *Calamopora* (bundle of reeds), and the only difference between it and *Syringolites* consists in the tube within a tube and the rows of septal spines on the tubular surfaces and in the tube, as shown in the figures. Geol. Mag. No. 180, p. 245.

† See a description of these curious creatures in S. A. Miller's N. Amer. Geol. and Pal. 1889, p. 52, from which most of this pretty picture of Niagara life is condensed; a book indispensable to the student of geology.


CXVI.
No. V b, Niagara Limestone fossils.
Caryocrinus urnatus. Hall,
Cyathocrinus, Hall,
Eucalyptocrinus decorus. (Hypanthocrinites
Hall
Lyriocrinus dactylus, Hall, (Marsupiocrinites)
Eucalyptocrinus cælatus.
Macrostylocrinus fasciatus.
Macrostylocrinus striatus. Hall
Melocrinus obconicus, Hall,
L. melissa,
IND. 1881.
PL. 15.
IND. 1881.

fore the next age set in. As for the graptolites they all perished in the Niagara age. *Holocystites* of 25 species is widely distributed and considered characteristic of the Niagara because not yet found in later formations. *Eucalyptocrinus* is still more abundant and a wide spread genus. Of characteristic brachiopod shells *Orthis elegantula*, *Orthis flabellum*, *Orthis hybrida* seemed to have lived all around the world. So also the trilobites *Calymene blumenbachii* and *Illænus barriensis*. These stamp the rocks that contain them as Niagara everywhere, or are supposed to do so.

A magnificent *Nautilus-like* shell (*Lituites bickmorianus*) has been found in the magnesian limestone of Niagara age at Wabash City in Indiana,* two inches wide at the mouth, straight for 4 or 5 inches, and then whorled tightly twice to a blunt inner end, so that the whole length if uncoiled would be 20 inches, measured along the central syphuncle. There are something over 40 ribs running diagonally around the shell.†

A similar shell (*Lituites giganteus*) is found in rocks of this age in England.‡

Fossil evidence of the existence of Niagara in Pennsylvania.

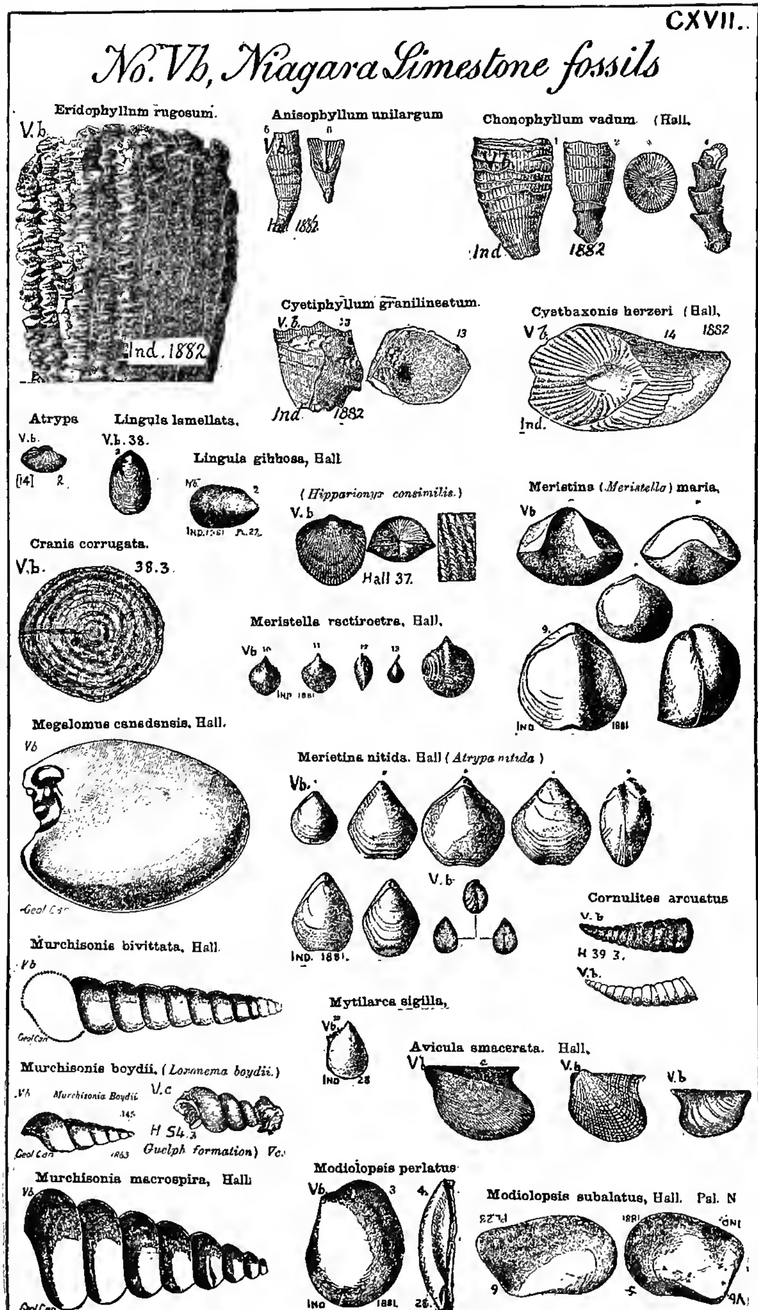
The question of the existence of the Niagara limestone formation in Pennsylvania was an interesting one when the first survey of the State was made. Prof. Rogers believed that it did not exist in the State.§ Dr. Barrett at Port Jervis on the Delaware river claims to have found *Halysites catenulatus* and many other Niagara fossils in the lower beds of the Nearpass quarry section; and Prof. White was at one time disposed to identify his Bossard-

*See Bull. Am. Mus. N. H. N. Y. Vol I, N. 6, 1885, picture and description by R. P. Whitfield. See fig. on plate CXVIII above.

†It would be called from its general shape a *Trochoceras* but for the three deep lobes at the mouth of the shell and if it were not coiled on a plane.

‡See Murchison's figure of it in Siluria, plate 33. On page 259 (1859) he calls it "one of the finest fossils from Leintwardine and Malvern."

§Geol. Pa., 1858, p. 135.


CXVII.
No. Vb, Niagara Limestone fossils
Eridophyllum rugosum.
V.b.
Ind. 1882
Anisophyllum unilargum
Chonophyllum vadum. (Hall.
Ind
1882
Cyetiphyllum granilineatum.
Ind
1882
Cystbaxonis herzeri (Hall.
1882
Ind.
Atrypa
Lingula lamellata.
V.b.
V.b. 38.
Lingula gibbosa, Hall
(Hipparionyx consimilis.)
V. b
Hall 37.
Meristina (Meristella) maria.
Vb
Crania corrugata.
V.b.
38.3.
Meristella rectirostra, Hall.
Vb
Megalomus canadensis, Hall.
Vb
Meristina nitida. Hall (Atrypa nitida)
Vb.
V.b
Cornulites arcuatus
V. b
H 39 3.
V.b.
Murchisonia bivittata, Hall.
Vb
Mytilarca sigilla,
Vb
Avicula emacerata. Hall.
V.b
V.b
Murchisonia boydii. (Loxonema boydii.)
Murchisonia Boydii
V.c
H 54.3
Guelph formation) Vc.
Murchisonia macrospira, Hall.
Vb
Modiolopsis perlatus
Vb
Modiolopsis subalatus, Hall. Pal. N

ville limestone as Niagara.* Prof. Cook suggested in 1868 that his "Medina sandstone" immediately under his "dark cement" bed might be Niagara.† Prof. White could not distinguish any Niagara beds from the Clinton beds in Columbia and Montour counties.‡ On the other hand, he found vast numbers of *Halysites catenulatus* in a 20′ limestone lying 32′ over the Bossardville limestone.§ Prof. Claypole found no *Halysites* in Perry county, nor any Niagara fossils in the upper part of No. V where they should be expected; in their place he found a mixture of Clinton and Lower Helderberg fossils.‖ Prof. White, however, found *Favosites niagarensis*, or something very near it, in his *Barre limestone* beds, which overlie the Clinton shales along Tussey's mountain in Huntingdon county.¶ Prof. Stevenson saw no distinct traces of Niagara between the Salina and Clinton in Bedford county, except perhaps some thin limestone layers in the lower shales of the Red Ridge; the uppermost of which layers alone was fossiliferous, but it was crowded with a *Trematospira.* He found *T. aprinis* also in the highly fossiliferous shales at the Kemble Co.'s Clinton fossil ore mine.** He found a *Trematospira* in the massive No. VI limestones.††

This is one of the cases where an acknowledged charac-

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* Report G6, p. 145, 1882.

† Nearpass quarry station in Geol. N. J., pp. 155, 157.

‡ Report G7, 1885, p. 110.

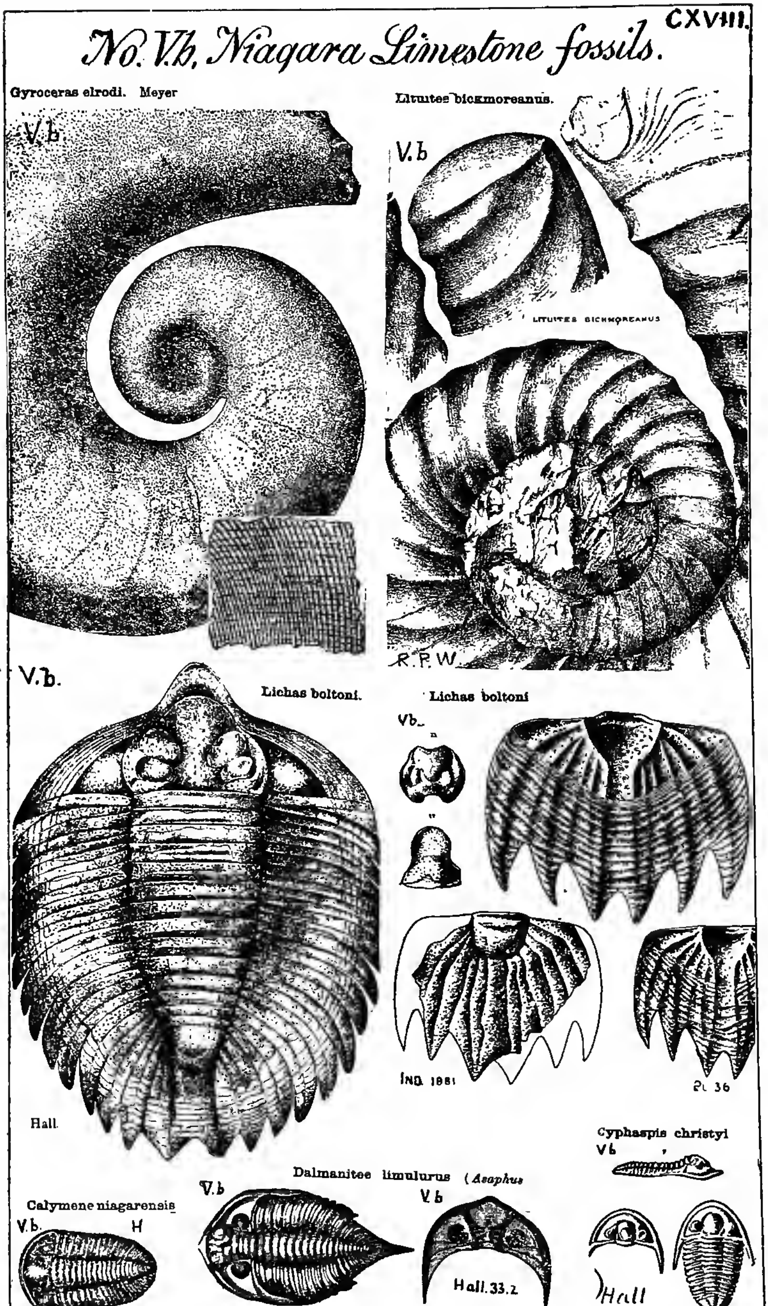
§ G7., p. 244.

‖ Report F2, 1885, p. 55.

¶ Report T3, 1885, p. 132. In the Logan gap section at Lewistown, Mifflin county, underneath 185′ limestone, 470′ water lime, and 350′ Salina, comes a $3\frac{1}{2}'$ bed of solid non-fossiliferous limestone and then 70′ of red and green shales, in the midst of which is an 8′ bed of tough laminated gray lime shale, and towards the bottom some 2″, 3″ blue limestones. These rest on 432′ of Clinton No. V red shale, etc. (F, 1878, p. xxiv). The name *Niagara limeshales* is given to these $73\frac{1}{2}'$ of measures merely because they seem to occupy the proper horizon for that formation, and for no other reason; but they seem to be identical with the *Barre limestones* of White.

** Report T2, 1882, p. 90, 144.

†† T2, p. 155. *T. granulifera* and *T. quadriplicata* are in No. III (Cincinnati group); *T. mathewsoni*, McChesney, in the *Niagara; T. camura, costata, globosa, imbricata, multistriata, perporata, rectirostris, simplex*, all L. Helderberg species of Hall; *T. gibbosa, hirsuta, nobilis* (Hall), and *liniuscula* (Winch.) in Hamilton. (See Miller's Am. Pal. Fos. p. 139.)


CXVIII.
No. V.b, Niagara Limestone fossils.
Gyroceras elrodi. Meyer
V.b.
Lituites bickmoreanus.
V.b
LITUITES BICKMOREANUS
R.P.W.
V.b.
Lichas boltoni.
Lichas boltoni
Vb
IND. 1881
Pl. 36
Hall
Cyphaspis christyi
Vb
Dalmanites limulurus (Asaphus
Calymene niagarensis
V.b.
H
V.b
V b
Hall.33.2
Hall

teristic fossil fails as a sure guide to a formation. Hitherto the chain or necklace coral *Halysites* has been regarded as positively identifying the Niagara formation in America, and as affording a certain basis for identifying that stage of the Upper Silurian system in America with the Wenlock formation in England and corresponding rocks in Europe.*

But the chain corals first appear in the Lower Silurian limestones.† If they had a great development in the Niagara stage of the Upper Silurian there is no good reason why they should not have continued up into Helderberg time. Finding them in and over the Bossardville limestone in Pennsylvania is no certain proof that this limestone is of Niagara age.

The most important point is that the *Halysites bed* in Montour county, Pa. lies only 175′ beneath the Oriskany sandstone No. VII, and 184′ above the Salina formation, which Prof. White recognizes in its triple subdivision, and measures there 1176′ thick, *beneath which* the Niagara formation if it exists ought to show its characteristic fossils.‡ The *Halysites bed* is therefore at least 1360′ higher in the series than the theoretical horizon of the Niagara formation. At this theoretical horizon he found no *Halysites*. The conclusion is that if *Halysites catenulatus* be characteristic of the Niagara in New York and Canada, it is not so in Pennsylvania, but that it is merely one of the many forms in the Lower Helderberg No. VI. §

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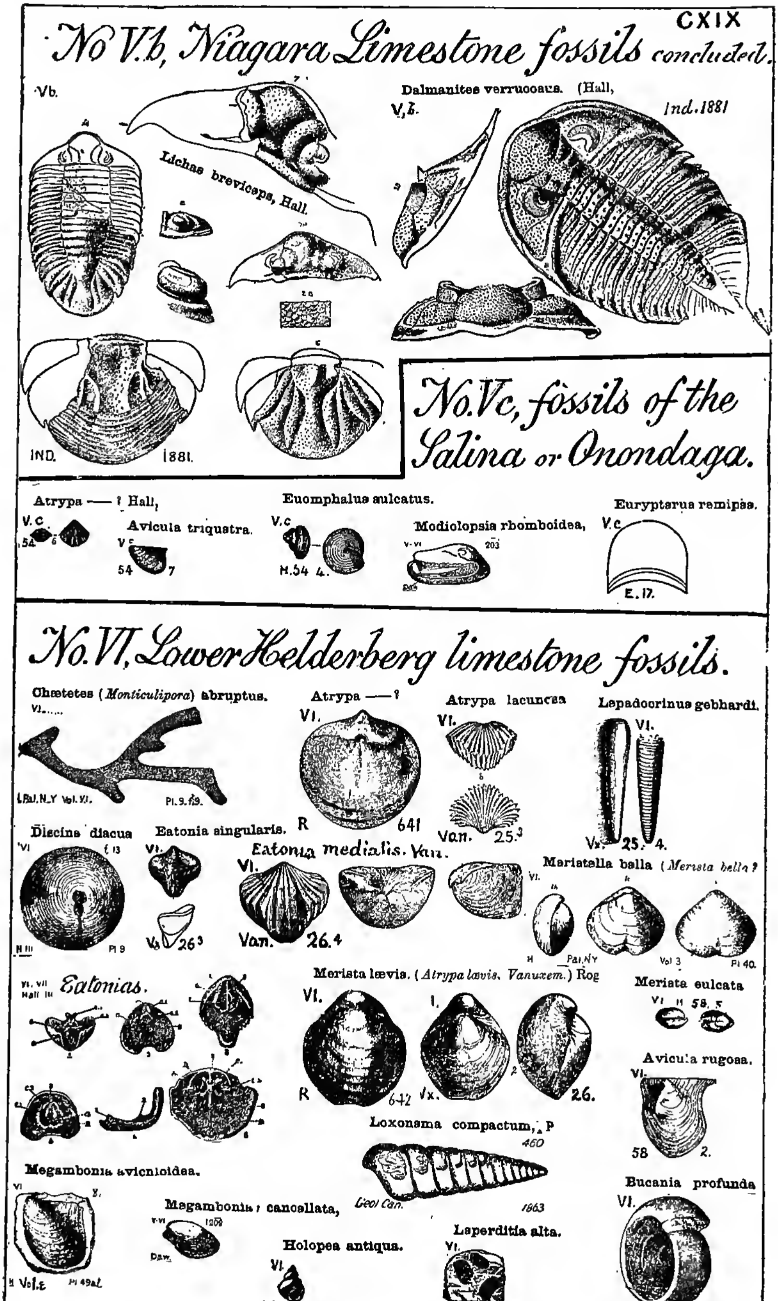
* *Halysites* (Fischer=*Catenopora*, Lamarck) has one Hudson River species, *H. gracilis*, and five Niagara species, *agglomeratus*, *catenulatus*, *compactus*, *escharoides*, and Troost's uncertain Tennessee *meandrina*, in America. In Europe, H. catenulatus (considered to be=Lamarck's *Cat. esch.*) begins in Llandeilo, and Caradoc, and continues up through Llandovery to Wenlock (i. e. fr. No. II to No. VI). Other species are *approximata*, *communicans?*, *dissimilis*, *exilis*, *and labyrinthica*. (Bigsby's Th. Sil. p. ii.)

† See Etheridge's Phillips Man, p. 73. Prof. Hall says he has seen the form of it in Hud. Riv. No. III, on Green bay in Wisconsin. Logan found it in Trenton limestone.

‡ G7, p. 89, 97, 101, 244, 245.

§ Prof. Claypole suggests that the accepted opinion that *Halysites* is necessarily a Niagara form has perhaps led observers in some districts to call strata Niagara, which are not such. The cement beds at Kingston N. Y., have been placed in the Niagara for this reason; but when traced into Pennsylvania they take their place (as cement beds also) at the base of No. VI, where *Halysites* also occurs.


CXIX
No V.b, Niagara Limestone fossils concluded.
Vb.
Lichas breviceps, Hall.
IND. 1881.
Dalmanites verrucosus. (Hall,
V,b.
Ind. 1881
No. Vc, fossils of the Salina or Onondaga.
Atrypa —— ? Hall,
V.c
54 6
Avicula triquetra.
54 7
Euomphalus sulcatus.
V.c
H.54 4.
Modiolopsis rhomboidea,
V-VI 203
Eurypterus remipes.
V.c
E.17.
No. VI, Lower Helderberg limestone fossils.
Chætetes (Monticulipora) abruptus.
VI.
Pal.N.Y Vol. VI.
Pl. 9. f9.
Atrypa —— ?
VI.
R 641
Atrypa lacunosa
VI.
Van. 25.3
Lepadocrinus gebhardi.
VI.
25. 4.
Discina discus
VI
Pl 9
Eatonia singularis.
VI.
26 3
Eatonia medialis. Van.
VI.
Van. 26.4
Meristella bella (Merista bella ?
VI.
Pal.NY Vol 3 Pl 40.
VI. VII Hall III
Eatonias.
Merista lævis. (Atrypa lævis. Vanuxem.) Rog
VI.
R 642 1. 2 26.
Merista sulcata
VI H 58. 5
Avicula rugosa.
VI.
58 2.
Loxonema compactum, P
460
Geol Can. 1863
Megambonia avicnloidea.
VI
H Vol. 3 Pl 49a.
Megambonia ? cancellata,
V-VI 1209
Daw.
Holopea antiqua.
VI.
58. 4.
Leperditia alta.
VI.
58
Bucania profunda
VI.
Van 25 2

Fossils of the Guelph or Upper Niagara.

This formation in Canada West is a set of passage beds from the Niagara up into the Salina, only 160′ thick, and very local, composed of magnesian limestones rich in Niagara fossils but destitute of Echinoderms. It occurs also in northwest Ohio; but nowhere else outside of Canada. Some prefer to class it with the Salina (Onondaga of New York) because it contains *Murchisonia boydii* and *Cyclonema sulcatum.* Its most common species of shell *Megaloma canadence* and its *trimerella grandis*, are both found in the Niagara rocks. Its own peculiar forms seem to be *Pantemerus occidentalis*, *Murchisonia bivittata*, *Murchisonia longispira*, *Subulites ventricosus*, *Pleurotomaria solaroides and Dinobolus galtensis.**

Fossils of the Salina.

The Salina formation was originally named in 1839 from Onondaga county, N. Y. and described by Vanuxem and Hall in their reports of 1842, 1843. It was called the Salt group because it contained the Syracuse salt deposits; the lower part being our Bloomsburg red shale; its middle part full of hoppers of gypsum; its upper magnesian beds are capped by the Waterlime or hyraulic cement beds, which in Pennsylvania have usually been thrown into No. VI.† East of Herkimer where the Niagara beds thin out the Salina rests directly on the Clinton, as it seems to do in Pennsylvania. The fossil species of the Clinton do not pass up into the Salina: as if the gypsum waters killed off the Clinton life. The whole group is 1000′ thick in Wayne Co. N. Y. and thins to 300′ on Grand river in Canada West, the lower red shale portion beneath the gypsum beds having disappeared. It forms the isle of Mackinac; and is only 50′ thick in N. W. Michigan. It runs from the head of Lake Erie westward, and it has outcrops in Ohio. It is 10′ to 75′ in Missouri; but is unknown south of Pennsylvania.

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*L. A. Miller, p. 53.

†The sulphate of magnesia occurs in needle-shaped crystals which when dissolved leave needle-shaped cavities lined a black substance originally petroleum. Acid sulphur springs occur along the present outcrop.

It is nowhere very fossiliferous, and usually fossils in it are hard to find. Its New York species are *Orthoceras sublæve*, *Euomphalus sulcatus*, *Avicula triquetra* with the two Guelph species *Murchisonia boydii, and Cyclonema sulcatum*, with indistinct and unnamed species of *Spirifera*, *Atrypa*, and *Cornulites*. *

Fossils of the Water-lime.

The Water-lime (if not the base of VI) is characterized in New York in its bottom brown limestone by *corals*, *crinoidal fragments*, and a small *Orthoceras ;* also by the varinos species of the curious crustacean *Pterygotus;* by *Eurypteris remipes ;* and by the lamelli branch shell *Pterinea rugosa.* The widest spread Water-lime fossil is *Pleurodictyum problematicum.* All the quarries smell of petroleum, and many of the quarry beds are fetid.†

Fossils of V on the Delaware.

The Clinton red shale formation along the outcrop of which the Delaware river flows from Port Jervis to the Delaware Water Gap, are not exposed sufficiently to make it certain that they are so utterly non-fossiliferous as they are reported to be. But west of the Water gap they fill the valley between the mountain and Godfrey's ridge, and continue west as the valley rocks of Aquanchicola creek to the Lehigh Water Gap. Prof. White states in his Report G6, p. 148, that "not a single fossil of any description was seen in these red rocks," their iron being disseminated, and nowhere collected into beds of fossil ore. Had there been shell beds, they would certainly have been converted into iron ore beds.

Over the red beds lie the *Poxono Island limestone beds*, which he assumes to be the base of the Lower Helderberg series. But in these beds are thin layers crowded with *Beyrichias* and ground up small shells of other undetermined species.

Over these lies the *Poxono Island shales*, at several lo-

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*S. A. Miller, 1889.

†See I. C. White's account of the quarries of VI in the Montour region in following chapters.

calities on the river, Broadhead's creek, and in Cherry Valley, one mile west of Stormville. They are entirely non-fossiliferous for 200′; and also on the Lehigh river.

Over these shales comes the *Bossardville limestone*, making a good hydraulic cement. It is reported to be also entirely non-fossiliferous for 90′. Although it often shows a prismatic structure (*Styolites*) like the Niagara limestone of New York, and although Dr. Barrett claims to have found *Halysites catenulatus* and other well known Niagara fossils at Port Jervis in beds which seem to hold about the same place in the series Prof. White rejects the inference of Niagara age and makes it one of the Lower Helderberg subdivisions of No. VI.

Over this lie the *Decker's Ferry shales*, and over them the *Decker's Ferry sandstone*, and over this the *Decker's Ferry limestone*, with iron ore and ochre. The sandstone is "crowded with fossil shells," poorly preserved casts, so that only a small *Chonetes* and a large *Avicula* could be recognized."

Over the Decker's Ferry series, come the Stormville series; the bottom subdivision being a hydraulic cement-bed, or *Water lime*, 5′ thick, occasionally 10′ non-fossiliferous; but just under it are millions of the little Clinton phyllopod shell *Leperditia alta.*

The great *Stormville limestone* series 75′ to 100′ thick certainly represents the Lower Helderberg No. VI, and is crowded with fossils of that age, although among them is the *Favosites niagarensis*, and the inevitable *Leperditia alta.* I can see no great objection to carrying up No. V to the base of this rock; but, following Prof. White in his Report G6, all the subdivisions above the red shale are described in the following chapters under the head of No. VI. Geologists should be consistent; but what can poor geologists do when Nature is the mother of inconsistency.

Fossils of V in the Montour region.

In the section below Danville in Prof. White's Report G7, p. 111, nearly 1000′ of shales and limestones intervene between the top of the Medina No. IV and the Salina

(Bloomsburg) red shale, IVc; and many of the beds are very fossiliferous. The fossil ore bed is double and the slate parting of 2′ or 3′, as well as the ore beds themselves, carries *Avicula leptonata*, *Strophomena depressa*, *Strophomena alternata*, *Atrypa reticularis*, *Rhynchonella robusta*, *Rhynchonella neglecta*, *Beyrichia lata*, *and Calymene clintoni;* a list which might be largely increased by systematic collecting.

The Lower Salina (*Bloomsburg*) *red shale* about 450′ thick seems to possess only one fossil, a poorly preserved and undetermined species of *Lingula*, found at Chulasky Furnace.

The Middle Salina variegated shales and limestone beds, about 400′ thick, seem to be quite non-fossiliferous.

The Upper Salina limestone and lime-shale beds, about 330′ thick from the lowest red bed up to the base of the Bossardville limestone (which Prof. White assumes as the base of VI) did not furnish a single fossil.

The Bossardville limestone, which carries lead and zinc, has a list of fossils which will be given in the next chapters. But it is well to note that it contains not only the Niagara form *Halysites catenulatus*, but also the Clinton form *Leperditia alta*, as on the Delaware; to say nothing of *Atrypa reticularis*, *Strophomena depressa*, *Strophomena rhomboidalis*, var. *rugosa*, and two or three species of *Beyrichia.*

Fossils of V in Perry County.

In Perry County Prof. Claypole sums up the list of Clinton fossils in the preface to Report F2, thus:—

The Clinton lower green shale is very barren, only a few unstudied forms were found in it.

The Iron Sandstone is often very fossiliferous with *Beyrichia lata* and *Calymene clintoni*, and in it he found the until then oldest trace of a fish, a spine which he named *Onchus clintoni;* * and with these broken scales and plates,

* Described by him in the Quarterly Journal of the London Geological Society, Dec. 14, 1884. See Dict. Fossils, p. 4. The reduced figure is given on plate.

and small pellets which are probably the coprolites or dung of the fish.

The *Upper green shale* has furnished many specimens of *Beyrichia lata*, *Calymene clintoni*, and *Calymene niagarensis*, which allies these shales to the Niagara limestone formation of New York.

The Ore sandrock and the *Sandvein ore bed* are often abundantly fossiliferous, but the forms are badly preserved: *Beyrichia lata*, *Calymene clintoni*, *Ormoceras vertebratum.*

The overlying limestone and shale beds are not fruitful of Clinton forms, but here we find *Lingula oblonga.*

The Niagara division of V is not recognized by massive limestones, and is only indicated by one or two of its characteristic fossils.

The Salina red shale has so few fossils in it that *Leperditia alta* stands almost alone; but the broken fragments of what are apparently fish-scales are found at a few localities.

The Variegated shales are almost as barren; but *Leperditia alta* is very abundant in the beds near the top; and in the *Bloomfield sandstone*, at the very top, two kinds of fish scales (*Palæaspis americana* and *Palæaspis bitruncata*) and small fish spines with fluted surfaces (*Onchus pennsylvanicus*) were found.*

In the Waterlime, which Claypole accepts as the uppermost member of V, the only common and abundant fossil is *Leperditia alta*, some of them extraordinarily large. Here a good specimen of the crustacean *Pterygotus osborni* was found in Juniata county.

Fossils of V in Mifflin, Huntingdon and Blair.

In Mifflin county, collections were made by C. E. Hall and A. Hale, in 1875, at McKee's ore bank in Ferguson Valley, 7 miles from Lewistown, and from an ore bank further west; also at Matilda furnace. In 1874 collections were

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* Preliminary description in American Naturalist, p. 1222, Dec. 1884. See Dictionary of Fossils, P4 4.

made here by C. E. Hall and W. A. Fellows. The same year others were made at McKee's ore bank by G. H. Christian, C. A. Ashburner and A Hale.*

The fossils were found in the *shales above the fossil ore beds*:—*Avicula emacerata, Actinopteria emacerata, Avicula rhomboides, Atrypa reticularis, Atrypa plicatula, Beyrichia lata, Beyrichia symmetrica,* Crinoid stem fragments, *Dalmanites limulurus* (abundant and many of them in fine preservation), *Homalonotus delphinocephalus* (large and small, heads, tails and bodies, mostly broken),† *Lyrodesma poststriatum, Leptæna striata, Leptocœlia hemispherica, Modiolopsis subalata, Modiolopsis subrhomboidea,* Simpson, 1889, *Nucula sinuosa,* Simpson, 1889 (many), *Nucula subtrigona,* Simpson, 1889 (many), *Orthis elegantula* (abundant).‡ *Orthis elegantula,* var. *Orthis subcircula,* Simpson, 1889 (three on Spec. 501–41), *Platystoma niagarense* (two specimens), *Rhynchonella stricklandi,* § *Rhynchonella bidens* (?) *Rhynchonella hemispherica* (two on Spec. 502–15), *Rhynchonella* (*Stenochisma*) *neglecta, Spirifera staminea, Strophodonta profunda, Strophodonta striata* (numerous), *Strophomena rhomboidalis* (numerous), *Strophomena depressa, Streptorhynchus tenuis* (very numerous), *Streptorhynchus subplana, Tellinomya* (*Palæoneilo*) *cuneata,*‖ Simpson, 1889, (501–20,–24,–48,–201), *Tellinomya* (*Palæoneilo*) *diminuens,* Simpson, 1889, (501–43, 502–10,) *Tellinomya elliptica,* ¶ *Tellinomya machæriformis* (502–44).

In the *Clinton lime shales* were collected at Matilda furnace and Orbisonia the following:—*Actinopteria emace-*

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*These collections are in the cabinet of the survey, now (1892) in the Museum of the University of Pennsylvania, W. Philadelphia. They were carefully revised by G, B. Simpson in 1888, and published in Report OOO, Catalogue, p. 192 ff; Nos. 501–1 to 505–45.

† Some are in good condition, e. g. 502–18 ; Spec. 502–48 has on its face two heads and four tails, with *Strophodonta striata* and *Rhynchonella neglecta.*

‡ Frequently in company with *Streptorhynchus tenuis.*

§ Many specimens, one of which, 505–32, may be a new species.

‖ No. 502–16 is marked *Nucula sinuosa,* N. S. Simp. with *Tellinomya* (*Pyrenomæus*) *cuneata.*

¶ No. 502–21, *T. elliptica* "compare *Glossites,* Hall, Vol. V."

rata, *Atrypa nodostriata* (507–15), *Atrypa reticularis* (very numerous valves, sometimes attached), *Avicula rhomboidea*, *Beyrichia lata* (numerous ; many on one specimen), Crinoidal fragments of stems, *Dalmanites limulurus* (very numerous, with fragments of this or other trilobites), and a Gasteropod fragment, *Homalonotus delphinocephalus*, *Lyrodesma poststriatum* (507–17), *Modiolopsis subalata*, *Nucula subtrigona*, *Orthonota* (*Orthodesma*) *curta* (See Hall Vol. 2, pl. 27), an undetermined species of *Platystoma*, numerous obscure plant remains. *Rhynchonella* (*Stenochisma*) *neglecta*, *Rhynchonella stricklandi*, *Strophomena striata* (numerous), *Strophomea rhomboidalis*, *Strophodonta striata*, *Strophodonta profunda*, *Tellinomya* (*Palæoneilo*) *cuneata* (numerous).

Beyrichia lata beds occur at Orbisonia 60′, 80′ and 140′ above the base of the *Clinton limeshales*. (OOO, p. 202.)

At Bell's Mills in Blair county, C. E. Hall collected from the *Clinton lime shales* : *Atrypa reticularis*, *Atrypa intermedia*, *Atrypa neglecta*, *Dalmanites limulurus*, an *Illænus* (impression too indistinct for specific determination), two casts of a *Nucleospira*, *Orthis elegantula*, *Orthis flabellum*, *Orthis hybrida* (numerous), *Rhynchonella lævis*, Simpson. *Streptorhynchus subplana* (numerous), *Strophodonta striata* (numerous), *Strophodonta depressa*, *Strophomena rhomboidalis*, and a *Spirifera*.

Near Hollidaysburg, Sanders collected from the fossil ore above Jos. Patton's limestones quarry beds, *Leptocoelia hemispherica*, and several undetermined *Rhynchonellas*. The same at the Cambria Iron Co.'s slope near Frankstown ; and the same from the roof slate of the Frankstown ore.

Fossils of V in Bedford and Fulton counties.

At the County Farm in Bedford township where a pit in the ore found the bed 14″ thick the shales overlying it are ferriferous and very fossiliferous, holding *Spirifera*, *Strophomena*, *Orthis*, *Rhynchonella*, *Streptorhynchus* and the trilobite *Delmania* (T2, 140). At the Kemble ore mines the synclinal yellow shales are rich in fossils. At the

Wolfsburg Kemble mines the shales are very fossiliferous; holding *Caninia* (*Zaphrentis*), *Spirifera niagarensis*, *Strophomena rhomboidalis*, *Streptorhynchus subplanum*, *Rhynchonella neglecta*, *Orthis elegantula*, *Trematospira aprinis*, *Aviculopecten? Bellerophon*, and two trilobites, *Dalmania limulurus and Bumastis barriensis* (T2, 144). *Caninia* is also found in No. VI (T2. 88,121, 134, 149. 159). At the Weaverling tunnel of the Kemble Co. the yellow shales show among other fossils *Streptohynchus subplanum Rhynchonella neglecta*, and the trilobite *Dalmania limulurus* (T2, 150). At the Walters' mine the upper layer of ore contains well preserved fossils, among which are prominent *Spirifera niagarensis*, *Streptorhynchns subplanum*, *Rhynchonella* and the coraline *Favosites* (T2, 153). *Favosites helderbergiae* is characteristic of the cherty beds of No. VI (see T2, 121, 134, 159, 187). In Hopewell township on the Methodist Church road half a mile from Yellow creek, a bed of silicious ore 2″ thick lies in shales containing *Orthis, Leptocœlia and Streptorhynchus* (T2, 198). *Leptocoelia imbricata* crowds a thin layer in the limestones of No. VI at Bedford, and is well exposed under the African church (T2, 149). *Leptocoelia flabellites* is a fossil of No. VII (T2, 104). Near Centreville many of the Salina beds in the drab shales contain *Leperditia alta*, which is in fact characteristic of this horizon everywhere in middle Pennsylvania (T2, 137, 140, 144, 148, 155, 196,). *Leperditia alta* is the only fossil seen in what Dr. Stevenson calls his Lower division of VI, but which has been made, in harmony with the rest of the geology of middle Pennsylvania, the Upper and Middle Salina (T2, 89). Several miles north of Centreville at Bortz's fossil ore mine large blocks lie about the surface of the ground holding large fossil shells, which, especially a *Pentamerus*, have been dissolved away and become replaced by specular iron ore (T2, 138). *Pentamerus pseudogaleatus* is properly a fossil of No. VI (T2, 88, 104, 120, 156). Near the Evangelical Dutch church of Centreville fucoidal markings are seen on layers of greenish shale, alternating with red and yellow shale, under fine-grained red sandstone at the upper part of the Clinton (T2, 138).

Small fucoidal impressions on thin beds of limestone imbedded in greenish shales may be seen 60 or 70′ under Wilson's fossil ore bed near the road leading across Tussey mountain into Bean's cove (T2, 184). *Trematospira* in some places crowd the uppermost limestone bed of the Red ridge series which overlies the fossil ore bed more than 400′ (T2, 90) and corresponds to the Bloomsburg red shale.

CHAPTER LXV.

Formation No. VI, Lower Helderberg.

In pursuing the historical description of the Palæozoic Formations in Pennsylvania from the first great Quartzite age No. I, through the great Magnesian limestone age No. II, the great Slate age No. III, the great Conglomerate and sandstone age No. IV, and the great Iron-bearing and lime-shale age No. V, we reach a sixth stage of massive, non-magnesian, fossiliferous limestone deposits which, in one respect, is the most remarkable and interesting of the entire series. The preceding formations are measured by thousands of feet; this formation is nowhere more than a few hundred feet in thickness; but in these few hundred feet are crowded an unusual variety of rocks and affluence of animal remains. Yet it forms but the close of that long series of calcareous deposits which have been described in the last preceding chapters. As we have seen the great sand-beds of the Medina age followed by the sandy-shales of the Lower Clinton,—these by the calcareous variegated shales of the Upper Clinton, and the red shales of the Lower Salina,—and these again by ever-increasing limestone layers in the lime-shales of the Middle and Upper Salina,—there now follow almost pure limestone beds, thick and massive, merely parted by lime shales. A crisis in the Palæozoic history is approaching. The sea is shallowing. Living creatures are becoming more and more abundant. The smaller shells which lived before are replaced by, or have developed into larger shells; and among the trilobites appear articulated animals rivalling in size our modern lobsters. A world of coral-like animals flourish in extensive reefs; and the bed of the sea becomes a floor of sponges. It is the age of Stromatopora and Eurypterus. Suddenly this wonderful exhibition comes to an end. An invasion of sharp sand grains with a proportion of clay and a tincture of lime, formation No. VII, invades the ocean and covers up the dead body of its animal life. Almost a new order of nature is inaugurated. The Silurian times are ended, and Devonian times begin; new species and genera of animals appear; the great bucklered fish take possession of the sea; trilobites change their character and live in diminished numbers; black mud is poured from the rivers and settles down upon the ocean bed; the first intimation of the creation of coal is given for a moment and then withdrawn; the great water basin deepens; and ten thousand feet of sandy and muddy deposits fill it up again; until, finally, the age of the true Coal Measures sets in and the Palæozoic record of the world is made complete.

This is the part which Formation No. VI plays in the great drama, so far as we can contemplate it from Pennsylvania. In Europe the transition from Silurian to Devonian seems still more strongly marked. And yet there was no break in the order of succession; no suspension of the inflow of solid matter from the continent to the ocean; no dry land appeared above the surface of the water; no plane of erosion and non-conformability is to be found. Formation No. VII is not a continuous dividing floor. Although deposited generally beneath the sea which then occupied the present area of the United States it was not deposited everywhere. Its thickness varies from 200′ to nothing. Where it was not deposited the calcareous beds below it and above it come together, and lie in contact. The Stromatopora reefs of the Lower Helderberg are repeated in similar Stromatopora reefs in the Upper Helderberg; by which we can only understand that when they were destroyed or covered up in one place they continued to grow in another, and afterwards spread back to occupy their former homes.

The supposed limit of Silurian and Devonian.

American geology may be said to have commenced in 1835 with the great Surveys of New York, Pennsylvania and the Virginias, at least so far as concerns the strata and the fossils of the Palæozoic system. English geology may be said to have commenced in 1832 with the labors of De la Beche, Murchison, Sedgwick and Lyell. Thus, the great systematic names *Devonian*, *Silurian* and *Cambrian*, invented by the English, were adopted by American geologists. The hard and fast line which had been drawn between Silurian and Devonian on the other side of the Atlantic where disturbances (elevation and erosion) had occured was looked for on this side of the Atlantic and thought to be found at Formation No. VII. Some however drew the line at the top of No. VII, and others at the bottom; so that there has continued to be to the present time a difference of opinion between those who assign the limestone formation No. VI to the last hour of the Silurian day, and the sandstone No. VII to the first hour of the Devonian day, and those who prefer to make the Devonian age begin with the limestone deposits at the bottom of No. VIII. The discussion is a futile one. Were it possible to answer the question when did the Silurian age end, the answer would be barren of all utility. Such questions are of no importance whatever; and in fact, like many discussions in other branches of human knowledge, they originate not in facts but in prejudices, and confuse instead of enlightening the mind. It would be a happiness for all conscientious field workers in geology if these names Devonian and Silurian could be remitted to oblivion. Time and thought have been wasted in drawing across the great column of the rocks lines which nature ignores and the science of geology should repudiate. *

In Pennsylvania and New York the Potsdam sandstone, Formation No. I, has hitherto been considered the basal division of the Lower Silurian system; but recently it has been made the uppermost division of the Cambrian system by the United States Geological Survey; and it will no doubt continue to be so considered by American geologists.

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*Witness the long continued, elaborate and heated discussions among the foreign geologists respecting identity of the Devonian rocks with the Old Red Sandstone rocks; respecting the application of the names Silurian and Cambrian; respecting the subdivision of the Cambrian; respecting the identification of the New Red series of England with corresponding formations on the Continent, etc.

The great sandstone formation No. IV has been thus far accounted the bottom division of the Upper Silurian system; chiefly no doubt because of the general impression that there is no continuity of the slates of III upward into No. IV. Consequently seeing that the Lower Silurian system began with a great sandstone formation, and the Upper Silurian system began with a great sandstone formation, there has been a pronounced disposition to make the Devonian system also begin with a sandstone formation, namely the Oriskany Sandstone No. VII; its insignificent thickness compared with No. IV and No. I not being taken into account; and the imagination easily spreading it as a continuous sheet of division over the whole Appalachian sea bottom, although in fact it is actually only a local deposit over a considerable area.

In England no such sandstone deposit is found separating the Silurian and Devonian systems; but it is found in France.

In Pennsylvania it is an important formation, as will be seen in the chapter devoted to it; but it is so varied in its composition, and absent in so many places, that nothing but a slavish subserviancy to the English nomenclature can explain the importance assigned to it as a division mark between two ages of geological time. Palæontologists once thought and had no hesitation in saying that the whole world of created life came to an end at Formation No. VII, and that a new world was created entirely different from the preceding world. But the progress of that branch of geology has modified the sentiment; and it is doubtful now whether a greater fossil break occurs between Upper Silurian and Devonian than at any other stage in the development of animal forms. At all events, we cannot submit our classification of the mechanical deposits which proceeded without interruption in a water basin as vastly extended as the Appalachian ocean to the dictum of observers who busy themselves exclusively with nice distinctions of species and genera in animal forms; forms which in spite of these distinctions are essentially the same. We may therefore dismiss with these remarks the whole question of Silurian and

Devonian; although for convenience sake the words Silurian and Devonian will always be in use; and can always be safely used if their vagueness be kept in view, and no theoretical conclusions opposed to facts be drawn from them.

It cannot be too often repeated that our formations pass gradually and often imperceptibly into each other. Formation No. VI is merely a continuation and intensification of the limy beds of No. V. In one part of Pennsylvania a field geologist would fix the contact of the two formations at one horizon; in another part of the state he would find that horizon too obscure to be relied upon, or plainly replaced by another one. Different field workers fix the horizon each in his own district differently. By the assistants of the First Survey No. VI was supposed to begin with the cement-layers. Some of the assistant geologists of the Second Survey include the beds quarried at many places for hydraulic lime in the Upper division of the Salina. It is absolutely impossible to make an arrangement which shall satisify all the conditions at all places. It is even impossible to define sharply the group of cement-layers, for beds which are hydraulic in one place cease to be so at another locality. At all events, no particular hydraulic limestone stratum nor group of hydraulic limestone strata has been followed continuously by outcrops step by step from county to county. In fact hydraulic limestones are not confined to one horizon, but occur now here, now there, through a pile of lime shales many hundreds of feet in thickness. In this respect we have been prejudiced by the systematic geology formulated fifty years ago in the State of New York, where the formations lie flat and are comparatively thin; and where most of the hydraulic cement has been obtained from a few beds at a fixed horizon. These beds received in the New York reports of 1844 the very useful distinctive title of "*The Water Lime Group*" (with Eurypterus, etc.),—a group immediately overlying the salt and gypsum-bearing marls of Onondaga county; which in turn overlie the Niagara formation.

The order established by the New York geologists was:

No. VII. Oriskany sandstone.

No. VI. L. Helderberg:
- Pentamerus Upper limestone.
- Encrinal limestone.
- Delthyris shaly limestone.
- Pentamerus Lower limestone.
- Stromatopora limestone.
- Tentaculite limestone.

No. V.
- Onondaga:
  - Water lime beds; with Eurypterus &c.
  - Salina marls, with gypsum.
- Niagara limestone and shales with corals.
- Clinton shales, marls, iron ores etc.

It is not easy to use this original scheme of Lower Helderberg beds in eastern New York to describe our limestone formation No. VI. It will even not apply in central New York to the order of beds along the western extension of the lower Helderberg outcrop; much less to any order of beds observed in Pennsylvania.

The coral reefs of that age, as of other ages, were as locally various as they were widely distributed over thousands of miles of sea bottom. The waves played on every reef in different measure according to circumstances of open exposure or mutual protection; currents moved in many threads, assorting the coral sand, mixing or alternating it with mud from distant river mouths, and feeding colonies of shell-fish in various proportions of scarcity and abundance; each colony struggling for existence on the area which best suited it. When accumulations of silt overwhelmed and killed the reefs in one place they grew in another. One kind of reef invaded and encrusted another. Colonies of shells were forced to emigrate, and returned again to live at higher sedimentary levels in their old habitats. And all this went on continually everywhere throughout the expanse of an ocean of variable depth; charged in some parts with sand banks and mud flats; areas of which became occasionally isolated, and enclosed lagoons of extra-salt water concentrates under a torrid sun; conditions favoring briny percipitations. Other parts were too deep for the existence of the corals and mollusca which flourished on soundings. Into these deeper parts however their fragments were swept, mixed with the finer *débris* of the distant land. Thus the sea bed was slowly compacted chiefly of a paste produced by the grinding up of the masses of coral reef into fine calcareous meal spread by the ocean currents far and wide.

Considering the great variety of thickness, quality, order of subdivision, and fossil distribution, exhibited by the formation as a whole along its northern outcrop through New York, and its far more extensive and numerous lines of outcrop through Pennsylvania, it would be simply misleading to describe it as composed of any fixed number of beds, or groups of beds, arranged in a definite series, each group characterized by one or more species of organic form. All that can be said of it with truth is this :1, that it is mainly a limestone formation, underlying the whitish sandstone formation No. VII, and overlying the reddish shale formation No. V ; 2, that many of its beds are crowded with *Pentamerus*, *Delthyris*, *Tentaculites*, *Encrinal stems*, and masses of coral ; 3, that one or more of its beds are nearly solid layers of the sponge-coral *Stromatopora ;* 4, that at its bottom, whether included in it or not, are hydraulic-limestone beds, containing the remains of lobster-like creatures, *Eurypterus* and *Polygnotus :* and, 5, that it might perhaps be made by a downward extension to include the whole Salina salt and Niagara limestone formations of western New York and Canada, were it not for the extraordinary thickness of the Salina red shales, especially in Pennsylvania, by which the Niagara horizon is very far separated from the limestones of No. VI above.

The Helderberg wall of the Mohawk Valley.

In eastern New York, the valley of the Mohawk for a hundred miles west of Albany is bordered and overlooked from the south by an almost continuous wall of steep and lofty hills called the Helderberg ; supporting an upland which sloping gently southward is of special value to Pennsylvania as a great rain fall drainage ground for the North Branch of the Susquehanna river ; the head springs of which rise at the mountain brow, and in two instances, Otsego and Schuyler's lakes, are standing reservoirs of water.

Along the northern face of the mountain wall run continuous courses of horizontal strata, divisable into three groups, which may be studied wherever roads ascend the steep, in ravines which cut back into it, and especially along the extensive traverse valley of Schoharie creek, which heads far south in the Catskill mountains, trenches the Helderberg upland, and flows into the Mohawk, 30 miles west of Albany.

The whole body of strata in the mountain wall was origginally accounted one division of the Palæozoic series. It was called the *Helderberg division* and was subdivided into three groups *Upper*, *Middle* and *Lower Helderberg;* the upper and lower composed of limestone strata; the middle group composed of sandstone beds. No break in this series was recognized or could be recognized; the beds lying nearly horizontal, and in perfectly undisturbed sequence one above the other, from the bottom to the top of the mountain. In Mather's report of 1843 they are thus designated; —

1. Corniferous limestone (Seneca limestone, Selenurus limestone of Gebhard).
2. Onondaga limestone (gray sparry limestone).
3. Schoharie grit (Shell grit).
4. Cauda-galli grit (Cocktail grit of Dr. Eights).
5. The Oriskany sandstone (White sandstone of 1838).
6. Delthyis shaly limestone (Scutella limestone, Sparry limestone, Catskill shaly limestone).
7. Pentamerus limestone.
8. Water limestone (Tentaculite limestone, Water limestone, Hydraulic lime rock of Eaton).
9. Pyritous slates.

This noble outcrop of the Helderberg makes a complete semicircle around the base of the Catskill mountains, from Sharon Springs southeast to New Baltimore; thence south by Catskill village and Saugerties on the Hudson to Rondout; thence southwest by the Rondout and Mamkating valleys to the bend of the Delaware at the north point of New Jersey; entering Pennsylvania at Walpack bend in Monroe county; and so continuing into Schuylkill county, where it practically disappears, not to reappear until the Susquehanna river is passed, and zigzag outcrops commence in Perry county to traverse middle Pennsylvania.

With the Upper Helderberg limestone (the base of our No. VIII) and with the middle Helderberg (Oriskany) sandstone (our No. VII) we have at present nothing to do; but it is absolutely necessary for the understanding of formation No. VI in Pennsylvania, to understand the Lower Helderberg limestone formation in eastern New York, where its innumerable fossils, beautifully preserved, have been so carefully collected that the list is probably complete, and so magnificently figured and described in the immortal work of Professor James Hall, that nothing is left for the student to desire.

Delthyris shaly limestone.

The Delthyris shaly limestone at the top of the formation was subdivided into upper, middle and lower beds.

The *upper beds* of the Delthyris group are gray and coarsely subcrystalline limestone, full of shells, corals and encrini, each stratum having some species peculiar to itself; the discoidal pelvis of an encrinite (like *scutella*) being very abundant Vanuxem gave that name to the group. *Favosites* abound in some parts of it; and a branched encrinite is very common and characteristic of it.

An observer can scarcely cross the Helderberg out-crop belt anywhere without recognizing this particular group,* which moreover is frequently quarried for buildings. Stone fences around the fields offer a rich treat to the collector.

The *middle beds* of the Delthyris group are slaty limestone, full of many genera and species of shells, corals, encrini, and some trilobites; but their characteristic fossils are certain species of *Pentamerus;* they have therefore been called the Upper Pentamerus limestones. On the hillsides, east and west of Schoharie creek stone fences built of layers (1″ to 6″ thick) afford hand specimens ready for the collector, washed clean by the rain and illustrating the multitude and variety of its fossils.

The *lower beds* of the Delthyris group are abounding in fossils, of which the most abundant are three species of *Strophomena* (*rugosa*, *radiata* and *punctulifera*)*;* its character sufficiently different from the group above not to be mistaken by any careful observer. It is an important fact

*Travelers from Catskill to the Mountain House will see it on the road.

that while these lower beds cannot be found on Schoharie creek, nor west of it, they can be followed eastward and southward down the Hudson to Kingston, where they show a prominent and characteristic outcrop.

The perfection and beauty of the fossils of all the three groups just described is very remarkable; the minute corals when examined by a lens exhibit perfectly their internal structure. It may be affirmed with some confidence that the Delthyris group as a whole contains a greater variety of genera and species and a greater multitude of individuals than any other formation of the whole Palæozoic series. But that which will attract the attention of a superficial traveler who has his eyes open to geology is the immense number of shells of three kinds, *Delthyris*, *Atrypa*, and *Strophomena*, from one to two inches in diameter, and especially the *Strophomena* with its sharp straight edge and sharp angles.

The Pentamerus limestone sub-division of No. VI is in eastern New York a mass of gray and black slaty, sub-crystalline limestone 50′ thick; its beds separated by fine gray shale partings; full of many genera and species of fossils of a different kind from those last described. In some places its upper layers contain flat nodules of hornstone. Its name is derived from the large helmet-like shell called *Pentamerus galeatus;* an equally striking form abounds in it, the closely crimped shell called *Atrypa lacunosa;* it holds also a peculiar whorled shell, like a roll of ribbon, the *Euomphalus profundus;* but its special glory is a stone lily, with long flexible stem, and a plume of arms which rise from a cup at the top of the stem, the *Lepocrinites* (*Lepadocrinus*) *gebhardii*. The cup, separated from its stem and arms, is found in great abundance in the upper stratum at Schoharie, while the separate plates of the cup and the scattered disks of the stem pervade the formation.*

The Water Lime group in eastern New York was subdivided into an upper *Tentaculite limestone group*, and a

*The distribution of fossils through eight strata of the formation (quoted from Mr. Bonny) is given by Mather in his report of 1843, page 348, and is well worthy of study.

lower *Water Lime group proper.* At the present time all agree that the upper (*Tentaculite*) division is the only one which really belongs to the Lower Helderberg formation; but its name *Tentaculite* no longer applies exclusively, because the fossil animal so called has been found in earlier strata, many hundreds of feet lower in the series, in formation No. V, in Pennsylvania. The original name will always be retained however as distinctive of the lower member of the Lower Helderberg formation.

The Tentaculite upper beds are black or dark gray, slaty, compact limestone layers (1″ to 12″ thick), some of them sub-crystalline, holding several species of trilobites (*Asaphus and Calymene*).

The Tentaculite middle beds are black slaty compact limestone layers, full of *Tentaculites ornatus*, *Cytherina alta*, and *Orthis plicata* (fossils which we have already seen to occur in No. V) with some *Avicula rugosa;* and these are its characteristic fossils.

The Tentaculite lower beds are black and dark gray compact sub-crystalline limestones, full of *Favosites*, *Columnaria*, *Catenipora* and other coraline forms.

The Water Lime formation proper underlying the Tentaculite beds is a variable series of fossiliferous pure and bastard limestones, among which lie *hydraulic cement* layers.*

Fossils are rare, but among thefew occur species of chain coral (*Tubipora catenulata*). The bottom layer (8′) at Schoharie is full of globular masses of *Favosites*, which when cut and polished exhibit beautifully the internal structure. One specimen of a huge whorled shell 8″ long is figured by Mather on plate 20 of his report. In some places the rocks contain beautiful crystals of calc-spar, and of a compound of baryta, strontia and lime.

The above description of No. VI on its northern and eastern outcrop in New York has been here given not only for

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*An interesting section at Lawrence's quarry opposite Wilbur and Rondout creek is given in Mather's report of 1843, on page 331; 203′ of the Water Lime group lying directly on Hudson River slates No. III Here the whole of formations No. V and IV are absent.

its intrinsic importance as the first establishment of the geology of the formation 50 years ago; but because it indicates what we are likely to find where its southern outcrop enters Pennsylvania in Monroe and Carbon counties. We shall see in the next chapter how No. VI thins away in Pennsylvania, through Monroe and Carbon, into Lebanon and Dauphin counties. We are now to see how its northern outcrop in New York thins away westward in like manner. It must be kept in view that these two outcrops unite in a great semicircle following the Delaware, Hudson and Mohawk valleys; that the distance across the semicircle, on a north and south line drawn from the cement quarries at the Lehigh Water Gap to the Mohawk at Utica is 160 miles; that underneath the region measured by this north and south cross line No. VI lies concealed at depths amounting variously from 10,000′ to 20,000′; and therefore that we have no knowledge of it whatever until it rises to the surface along the two flanks of Montour's ridge, and in the counties of middle Pennsylvania west of the Susquehanna river.

Following its New York outcrop westward from Schoharie creek, where it is 400′ thick, 120 miles to Cayuga lake, where it is only 70′, we see its sub-divisions, so well marked at the east, gradually changing their character, and mingling their fossils by the time they reach Utica (50 miles). The Tentaculite limestone holds its own as far as Sceneateles lake (50 miles further) where the underlying cement beds get close up underneath the Oriskany sandstone No. VII. At Cayuga lake (20 miles further) all sub-divisions disappear and a general Tentaculite aspect pervades 70′ of strata. But in proportion as the Lower Helderberg formation diminishes the underlying Salina formation increases westward, being only a few feet thick on the Schoharie, and swelling to 700′ and 1000′ in central New York. In Michigan and Ohio it is but 40′ and 20′ thick.

Professor S. G. Williams of Cornell has recently studied and described these changes,* and makes the suggestion that the Salina in New York with its salt and gypsum beds,

*American Journal of Science 1886, page 139.

its red color, and its lack of limestone layers (explaining its lack of fossils) has a local character, and may be in fact not an older formation than the Lower Helderberg; but on the contrary may be perhaps a contemporaneous western deposit to which the eastern animals could not reach, or in which they could not live. This suggestion is valuable as drawing attention to the different kinds of deposits always accumulating in every extensive water basin; but considering our total ignorance of the local depth of the Appalachian sea in that age, the position and shape of its shores, the number, direction and power of the rivers which entered it, and the tidal currents which traversed it, we could hardly hope to convert such suggestions into scientific truths. A classification of rocks by fossils, except along some line of well exposed and continuous outcrops, must necessarily be vague, and will probably be delusive.

The one fact which the long New York outcrop of No. VI can teach us in Pennsylvania is, that the Tentaculite limestone group at its base is its most persistant and important member; so that if we can recognize that group on outcrops a hundred miles to the south, in middle Pennsylvania, we can feel sure of at least one tolerably well fixed horizon. Whether or not we can succeed in doing this will appear in the following chapters; Professor Williams' observations along the New York line are substantially as follows.

At Oriskany Falls, 5 miles above Utica on the Mohawk, the Oriskany sandstone No. VII is only 10′ thick. Beneath it are exposed in quarries 115′ of Lower Helderberg limestones No. VI. *The top layers* are a gray crystalline limestone, full of *Merista arcuata*, and occasionally *Strophomena radiata;* both of them Delthyris shaly limestone species. Twenty five feet below No. VII lies a bed (one foot thick) full of *Pentamerus galeatus*, *Pentamerus verneuilli*, *Rhynchonella mutabilis*, *Rhynchonella altiplicata*, *Atrypa reticularis*, *Orthis concinna*, *Strophodonta varistriata*, *Strophodonta punctulifera*, *and Strophodonta planulata;* occasionally also *Spirifera saffordi*, and several other species. All these occur also somewhat abundantly in the three or four feet of beds overlying the one foot bed; but beneath it, for 40′ downward there is a complete mixture of the fossils which in eastern New York are carefully separated into two groups, one belonging to Delthyris horizon above, the other to the Pentamerus horizon below; and it is quite possible that we should find the same mixture in the 25′ of gray beds above the one foot bed, and between it and No. VI, if the exposures were complete.

These gray beds immediately under the Oriskany sandstone are not at all like the Delthyris lime-shales of Schoharie; neither do they bear much resemblance to the rough Pentamerus beds of Schoharie. For about 90′ beneath them prevail blue limestoue beds pure enough for lime burning and furnace fluxing. The first 29′ (of this 90′) show few fossils save *Favosites helderbergiæ* and *Stromatopora*, which are tolerably abundant. The next lower 7′ are of bastard limestone, magnesian, ripple marked, and remarkably rich in fossils: fine large tail pieces of the trilobite *Dalmania pleuroptyx*, and occasionally *Discina discus*, and a peculiar *Conularia*. The next lower 45′ contain *Stromatopora*, *Favosites helderbergiæ*, *Strophodonta varistriata;* rarely *Spirifera vanuxemi;* and perhaps also *Euomphalus sinuatus*. Near the bottom of the section (115′ below No. VII) *Stromatopora* is abundantly associated with *Strophodonta varistriata*. Up the river may be seen still lower strata full of *Leperditia alta*, with a few *Spirorbis laxus*, and *Chaetites fructicosus;* while an occasional layer abounds in the *Tentaculite* which occurs in such myriads at a like horizon in Schoharie county.

Thus it appears that the Tentaculite limestone bottom sub-division of No. VI is well represented by its fossils in the section at Oriskany Falls; the uppermost beds of which however may possibly be identical with the Delthyris subdivision of No. VI, its special fossils being mixed with special fossils of the underlying Pentamerus sub-division through 50′ of beds. There is no trace of the eastern Upper Pentamerus group.

At Sceneateles lake further west we see under No. VII 12′ of blue silicious limestone beds full of *Stromatopora* *and Leperditia alta*, with *Spirorbis laxus*, *Holopea* (*Littorina*) *antiqua*, and occasionally *Favosites helderbergiæ* (a single specimen of *Spirifera vanuxemi* was found). Then, 3½′ of blue limestone. Then, 10′ of drab cement beds. Then, 9′ of blue limestone with many *Strophodonta varistriata* and *Spirifera vanuxemi*. Evidently, we have here in 35′ (perhaps 70′) under No. VII a Tentaculite fauna.*

At Cayuga lake, still further west, Professor Williams describes 65′ of limestone-beds lying between No. VII and certain gypsum beds below; † impure drab and blue limestones, with few fossils, the whole hitherto looked upon as belonging to the Water-lime formation (No. VI, Lower Helderberg proper being therefore supposed entirely absent).‡

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* Compare the *Spirifera vanuxemi* and *Tentaculites gyracanthus* found by Prof. Claypole high in No. VI, in Perry Co., Pennsylvania, (F2, pp 61, 182.)

† These plaster beds of Cayuga county, worked near Union Springs, have been hitherto supposed to be the Salina plaster-beds; but in the above section the limestones both over them and under them hold Water-Lime fossils, namely, *Eurypterus remipes*, *Leperditia alta*, *Nucliospira ventricosa*, *Meristella bisulcata*, and *Spirifera vanuxemi*. See S. G. Williams, Amer. J. S. p. 139, 1885.

‡ See Vanuxem's report 1842, p. 123; Hall's Palæontology Vol. III, p. 37. Afterwards a Tentaculite limestone was recognized at one place in Ontario county. Vanuxem in his report on the third or middle division of New York distinguished only three Lower Helderberg formations: Delthyris shaly limestone; Pentamerus limestone, and Water lime.

Delthyris shaly limestone. He describes the *top* beds as coarse, crystalline, gray limestone beds full of large encrinal disks; the *lower* beds as blue gray shales and fine blue limestones. In the shales are crowded multitudes of two species of *Delthyris* (*macropleura, and pachyoptera*) which give name to the formation; also great numbers of *Atrypa* of three species (*lævis, singularis, medialis*); also occasional specimens of three species of *Strophomena* (*punctulifera, radiata and depressa*) the latter having begun to live in an earlier age, as it is found among the fossils of the Niagara formation.* Besides the above forms there occur also five species of *Trilobites*; two species of *Platyceras*; *a Calceola*; *a Conularia*; *a Tentaculite*; and one coral, *Calamopora*. Vanuxem says that these shales disappear westward in Herkamer county, and their fossils with them, but the limestones continue as far west as Madison county and then disappear

2. *Pentamerus limestone*, his middle division 80′ thick on the lower Mohawk, thinning westward to 10′ at Oneida falls, is a series of rough building stone; the top beds full of flint balls; the lower beds crowded with *Pentamerus galeatus*, and *Euomphalus profundus*, besides other forms. In some

* This fact has a direct bearing upon the question of the existence of the Niagara formation at Port Jervis; for, as Prof. Hall remarks in his second volume, if *Favosites niagarensis* be rightly recognized by Dr. Barrett among the Favosite forms of his Favosite limestone, then it can no longer be considered characteristic of the Schoharie coraline limestone.

Recently however 15 species of fossils have been found in them, all Lower Helderburg species except two or three. *Stromatopora* is the most abundant of these fossils; both in the beds immediately beneath No. VII, and also in a solid bed near the bottom of the series which is exposed (4′ thick) at two places half a mile apart, and is therefore probably a continuous local sponge reef. In this Stromatopora bed occur also *Favosites helderbergiæ*, and a *Zaphrentis;* also sparingly *Nucliospira ventricosa*, and *Meristella laevis;* also a *Rhynchonella*, a *Lingula*, a large *Platyceras*, a branch *Fucoid*, and what may prove to be when good specimens are obtained a fluted *Orthoceras*. In this Cayuga section *Spirifera vanuxemi* occurs 10′ under No. VII, and also 8′ above the gypsum; also *Strophodonta* (*planulata?*) with *Megambonia aviculoidea* not far below No. VII; also *Strophodonta varistriata* and *Rhynchonella semiplicata*, tolerably abundant at two or three localities; also *Anatina sinuata* near the bottom.

The Gypsum beds of New York in No. VI.

The gypsum beds of New York crop out along a line from Madison county westward, past Salina and Syracuse to Buffalo. They are described as irregular masses of gypsum enclosed in marly shales, sometimes in two ranges sepa-

places there is an intermediate set of beds holding Gebhard's *Lepocrinites*. These three fossils, with a fourth, *Atrypa lacunosa*, were supposed to characterize this formation. It holds however other shells named by Conrad: *Atrypa semiplicata*, four species of *Strophomena* (*varistriata, rectilateris, impressa, elongata*); and two species of *Avicula* (*naviformis and manticula*).

3. *Water Lime group*, furnishing cement for the Erie canal locks and bridges; composed of an upper and a lower set of drab cement beds, separated by a middle set of dark blue limestones; the whole being 100′ on the Mohawk and 30′ at Cayuga lake. Most of the beds are solid 3 or 4′ thick; some of them showing the ribbon structure; sometime interlocking their surfaces with a fibrous or toothed structure. A few flint nodules occur, and some layers at the top and bottom of the group abound in casts of *Conularia* in flint. Six fossils characterize the Water Lime group; the first three, usually found together, strongly mark it, namely *Orthis plicata*, *Avicula rugosa*, and *Cytherina elevata*, (*alta*), The three others are *Tentaculites ornata*, *Littorina antiqua*, and *Atrypa sulcata*. These six, however, are not by any means the only fossil forms in the group, for there occur the trilobite *Agnostus*, a shell *Strophomena*, a chain coral *Catenapora* and others.

rated by a porous lime rock or shaly limestone bed with hopper-shaped cavities of rock salt.* These gypseous shales belong to the Onondaga or Salina formation.

But the principal gypsum quarries (at Union Springs in Cayuga county) turn out to be of a different and later age, or at least at a higher systematic horizon, quite inside the Lower Helderberg formation, No. VI, and only 70′ beneath the Oriskany Sandstone N. VII.† No Salina-like shales appear; no vermicular porous parting lime rock. The gypsum in two solid continuous beds, parted by a 3′ "slate" (interlaminations of gypsum and shale) has been tested for 3 miles, from 25′ beneath at Yawger's, to 100′ above lake level at Fitch's. The lower gypsum is a pretty regular 7′ group of laminated harder layers; the upper gypsum varies from 20′ to 0′ and was probably once regular.‡

All the gypsum beds show occasionally small spots and scales of sulphur; more in the upper; most in the "slate."

Gypsum beds in L. Helderberg.

These occur especially in the so-called "mud seams" which traverse the deposits, like dirt-faults in a bituminous, and rock-faults in an anthracite coal bed, where they indicate channel ways through the coal marsh. But these must have a different origin, for they are only from 1′ to 5′ wide, are often thinly laminated and contain a little gypsum and selenite; moreover the gypsum layers abut against them in

*See the N. Y. Reports of 1842, 3, 4.

†S. G. Williams, in Am. J. S., Sept., 1885, describes the new railroad exposure which settles this point:—Oriskany SS. 3′ 8″; drab L. S. 10′ outcrops of L. 46′; massive blue L. S. beds with *Meristella lavis*, *orthis oblata* (small), *Rhyn. semip.; Strophodonta varis.*, etc., 10′; drab L. S, with branching fucoid and *Nucleospira vent.*, 4′; concealed place, to which the gypsum beds are traceable along a ravine for 400 yards, 20′; thin blue L. S. and one thick one, 4′; drab L. S. with several thin blue beds, to lake level 16, holding near the middle (at several points) a head of *Eurypterus remipes*, and numerous *Leperd. alta*, *Nucleo. vent.* and *Merist. bisulcata*, badly preserved, but not doubtful. The whole section is of drab L. S., with frequent blue seams, some highly laminated and with 25 per cent. impalpable insolubie matter, some hydraulic.

‡It has evidently been planed away for it is everywhere covered with bowlder clay, except at Fitch's, where 12′ gypsum is capped by 6′ black dirt (? impure leached gypsum), 8′ drab shaly L. S. and 3 L. S., with *Spir. vanux.* a small *Lingula*, *Rhync. mutabilis* (?), and possibly a broken *calamite* (?).

a way to suggest that the mud veins are merely alterations of the regular formation, perhaps by infiltration from above.*

The drab or ash colored limestones above and below the gypsum beds are often highly laminated, very impure, and very absorbant of water.† It is easy to imagine them changed into gypsum beds by sulphur spring water; the amount of change being limited by the tight blue limestone floor. The *lime* layers of the parting "slate" have evidently been thus changed to gypsum, while the alternate *clay* layers remain unchanged. The gypsum itself is a grey mixture of 80½ per cent sulp. lime, 14 per cent earths, 5 per cent carb. lime and magnesia, and 0.6 per cent phosphate of lime and organic matter.‡

Barytes in No. VI.

The sulphate of baryta has been mined to a small extent by the Harrisburg Mining Co., from a deposit on the outcrop of the limestones of No. VI, where it makes its anticlinal curve around the south end of the Black Log mountain in Fulton county, ½ mile N. E. of Fort Littleton. An analysis by McCreath of an average speciman of the massive granular bluish-grey ore taken from the mine gave: Sulp. baryta 95.22, sulp. strontia (which usually accom-

* Prof. Williams could examine but one of them, and found the lower gypsum represented in the mud-vein by black thinly laminated mud, and the "slate" above it represented in like manner by harder, thin-bedded ferruginous shale; the lamination of the mud appearing to correspond to that of the gypsum against which it abutted. I think however that it may fairly be questioned whether the "mud veins" do not represent the formation, and the gypsum merely stretches of it altered by warm sulphur springs coming from the deep. The scattered quarries do not inform us of the actual outspread of the gypsum. This hypothesis would assimilate these larger gypsum masses to the smaller ones in the Salina shales. In fact Prof. Williams cites "a small isolated mass of decomposed gypsum, possibly 10 cubic feet in dimensions "in the *lowest* limestone of his section, close to where he obtained fossils, and nearly on the same level."

† A hand specimen gained 3 per cent. in weight by soaking two hours, while a blue limestone specimen gained nothing. The drab limestone is therefore unfit for any but the roughest purposes (Williams).

‡ Williams. The same operation with a different kind of spring water has changed the original lime shales at Cornwall, in Lebanon county, Pennsylvania, into a mass of stratified and laminated sulphatic magnetic iron ore. See annual report of 1885.

panies) *none*, ox. iron and alumina 0.38, ox. manganese 0.05, lime 0.59, magnesia 0.18, carb. acid 0.65, water 0.23, silica 2.45,=99.75. Another (surface) specimen gave an almost identical analysis (M2, p. 309).

A bone cave in No. VI.

All limestone formations are more or less cavernous, but caves are common only in massive limestone strata. Very few caverns have been reported along the outcrops of No. VI, but one such has acquired some fame among local curiosity seekers and especially among palæontologists, or students of extinct animals.

Hartman's cave in Monroe county, now rechristened by the name of Crystal Hill Cave, is well known to the numerous summer resorters to the Delaware Gap hotels. It is in the Lower Helderberg limestone (No. VI) of Godfrey's ridge south of Stroudsburg. It was explored in 1880 by Dr. Leidy and Prof. Porter, under the guidance of Mr. T. D. Paret of Stroudsburg, and a trench dug in its floor of clay 10′ deep, covered by a thin layer of stalagmite, which again was covered by a foot of black friable earth mingled with animal and vegetable remains, from which shells, seeds and works of human art were sifted, examined, described and figured by Dr. Leidy, and published in 1889 in the Annual Report of the Geological Survey of Pennsylvania for 1887, to which the reader is referred. The figures will be given in the appendix to the dictionary of the fossils of Pennsylvania when published; and on a reduced scale in a future plate in this final report under the chapters devoted to the description of the fossils of the Pleistocene or Human era.

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* Proc. A. N. S. Philadelphia, 1880, page 346.

CHAPTER LXVI.

No. VI in Eastern Pennsylvania.

The Delaware river flowing between the State of New York on its east bank and Wayne and Pike counties, Pennsylvania, on its west bank, reaches the north corner of the State of New Jersey at Port Jervis (Carpenter's Point); turns at a right angle and flows southwest 25 miles to the corner of Pike and Monroe counties ; makes here the double horse-shoe (Walpack) bend; and then flows 12 miles onward to the Delaware Water Gap. Between Port Jervis and the Walpack bend, the river has made its channel in the soft outcrops of No. VIII, and at the foot of the north slope of a ridge of No. VII and VI in New Jersey. At the bend it cuts through this ridge where No. VII and VI stand vertical. From the bend to the Water Gap it has made its channel in the red-shales of No. V, at the south foot of the steep ridge of VI capped with VII. Broadhead's creek cuts through the ridge opposite the Water Gap, exposing its folded structure. From Broadhead's creek to Kellersville (8 miles) Godfrey's ridge (VI capped with VII) borders the red shale valley of Cherry creek, and then shuts in its head with two anticlinal spurs, approaching closely to the Kittatinny mountain near the Wind Gap. From the Wind Gap west to the Lehigh Water Gap the ridge, here bold enough to be called Dodendorf mountain, confines the valley of Aquanchicola creek, and presents continuous outcrops of No. VII, with VI often concealed at its base; and the rocks become vertical opposite the Lehigh Gap.

Along this whole line of 65 miles formation No. VI was studied with great care by Prof. White, and minute local descriptions of it are to be found in his Report of Progress G6, 1882. Its sub-divisions were named by him from localities where each exhibits itself under conditions most favorable for measurement,—names new to American geology, strictly geographical in character, and some of them of only local value. Yet, as will be seen in the next chapter, the sub-divisions of No. VI, thus established and named on the

Delaware, were found to hold good on the West Branch of the Susquehanna in Columbia, Montour and Northumberland counties, where he studied the same formation the following year, using the same names in his Report of Progress on those counties, G7, 1883. These names, however, could not be successfully employed on the upper Juniata, in Huntingdon county; and therefore do not appear in his Report of Progress on that county, T3, 1885. A different set of names for the sub-divisions of No. VI were adopted by Professor Claypole in his study of the formation on the lower Juniata in Perry county, as will appear in a subsequent chapter; and it is doubtful whether any system of names can be invented applicable to the formation throughout middle Pennsylvania, so various are the changes which it exhibits in different districts, analagous to those which have already been described in the State of New York.

The following generalized section of No. VI along its Delaware river outcrop must be taken with a certain latitude of interpretation, and corrected by the local sections which will be given afterwards:

Generalized section of No. VI on the Delaware.

VII.	Oriskany sandstone; alternate beds of quartz and calcareous chert, ...	50′
VI.	Stormville lime shales, ash colored or dark gray, fossiliferous; sometimes cherty and with limestone at base, ...	160′
	Stormville conglomerate; alternate beds of quartz conglomerate and pebbly silicious limestones, .	25′
	Stormville limestone, cherty, sandy, massive beds, abounding in fossils of which *Pentamerus galeatus*, *Stromatopora*, *Favosites*, and *Receptaculites* are especially numerous, ...	75′
	Hydraulic cement bed (Peth-stone of Cook), .	5′
	Limestone, bluish, shaly; the top layers containing vast numbers of *Leperditia alta*, ...	20′
	Decker's ferry sandstone, pebbly, very hard, often calcareous; full of *Avicula*, *Chonetes* and other shells, ...	15′
	Greenish shales, sometimes calcareo-silicious, . . .	15′
	Bossardville limestone (upper division) dark blue, almost black, splitting into thin slate-like layers; almost non-fossiliferous, ...	65′
	Bossardville limestone (lower division) dark gray, always banded or striped, often columnar (*Stylolites*), ...	25′

V.	Poxono Island lime shales, magnesian, buff,	200′
	Poxono Island limestone, fossiliferous,	5′
	Red beds of the Salina or Clinton,	

In Report G6 the Poxono Island shales and limestone are included in Formation No. VI; but in Report G7 they are excluded from it, and placed among the Salina strata; the Bossardville group being considered the bottom division of No. VI, and the equivalent to the Tentaculite limestone of New York; its very dark color being a characteristic mark of resemblance.* The quarry portion of it is the only limestone bed in No. VI which can be followed consecutively all along the outcrop westward into Carbon county.

The first local section to be given in explanation of this formation is that of Nearpass' quarry 1½ miles south of the river and about 4 miles southeast from Port Jervis or Carpenter's Point.

No. VI at Nearpass' Quarry.

Stormville shales; lime sand shaly beds; quite fossiliferous at the top and at various horizons lower down	150′
Pentamerus limestone; massive, cherty, silicious, very fossiliferous; *P. galeatus* being most abundant,	10′
Lime shales, silicious, mostly concealed,	75′
Limestone, silicious, massive,	8′
Stromatopora beds; limestone, massive, full of large corals; *Stromatopora* very abundant,	12′
Pentamerus limestone; blue; worked in the quarries; holds *P. galeatus* and *Tentaculites gyracanthus*,	12′
Nodular limestone; blackish; concretions,	13′
Curly limestone, shaly,	15′
Cement bed (Peth-stone; Geol. N. J. 155),	5′
Nodular limestone; top layers gray, bottom layers blue, compact, with concretions,	12′
Coraline limestone, shaly; abounding in corals,	14
Crinoidal limestone, gray, shaly; full of crinoidal fragments and corals,	15′
Greenish shales and shaly limestone,	10′
Chaetetes bed; limestone, massive, bluish gray with many crinoidal fragments, corals etc. *Chætetes* very abundant,	10′
Atrypa lime shales; *Atrypa reticularis* and *Chaetetes*,	2′
Bossardville; limestone slaty, non-fossiliferous,	3′
All below concealed; total exposure of beds, 366′.	

*If this identification be accepted, it will follow that the Peth-stone has nothing to do with the hydraulic beds of the Water lime (Salina) formation.

No. VI in Flat Brook Valley N. J.

These rocks are well exposed across New Jersey, along the northern side of Flat Brook valley, which runs parallel with the Delaware river and enters it at Walpack bend and Decker's Ferry; and they continue to exhibit themselves more plainly along the cliffs of the river.

No. VI west of the Delaware Water Gap.

From the Delaware Water Gap westward along Godfrey's ridge the upper half of the section grows sandy and pebbly; the upper limestone gradually thins away and disappears; so that at the Lehigh Water Gap No. VII rests on 170′ of sandy measures, which rest on 30′ or 40′ of Bossardville limestone (G6, 127). This is worthy of careful study; for, while No. VI diminishes in this long line of outcrop from 400′ to 210′, the overlying Oriskany sandstone (No. VII) increases from 50′ to 200′. At first sight one might conclude that this is a case of compensation in a deposit of solid matters floated into the sea, the lack of one kind of material being supplied by an abundance of another kind; and there are instances, probably at many localities, where such compensation has taken place. But that hypothesis will not apply in this case, if we may judge by what has taken place in New York, where as we have seen No. VI thins westward from 400′ to 70′, and yet No. VII, overlying it, is nowhere more than 20′, and in most places only 2 or 3′ thick, or absent altogether. While the Bossardville limestone (bottom of No. VI) was a continuous deposit maintaining its normal character, and the Oriskany sandstone (No. VII) was also a continuous deposit maintaining its normal character, the intermediate deposits gradually change their character, being limy at the eastern, and sandy at the western end of this special district. But when we try to form a picture of the operation, determine the direction of the ancient currents, or locate the special areas of animal habitation, we are completely lost and must give up the problem in despair. For the whole sea bed as it originally was is now unknown to us and these interesting deposits are concealed from view, without hope of ever being reached for examination by mining operations in the future. All we know or can ever know of Formation No. VI and its distribution over the bed of the ancient sea is a single line section along its outcrop, which merely teaches one set of its variations along that line, leaving the whole mass of its variations over an area of 1000 square miles or more a subject for the vaguest conjecture.

To make the contrast at the east and west ends of this 60 mile outcrop evident the following local section of the Lehigh river in Carbon county will suffice :—

No. VI at the Lehigh Water Gap.

Oriskany sandstone (No. VII.) a reddish gray, massive, coarse quartz conglomerate nearly destitute of fossils, .		200′
Cherty sandstone, calcareous with fossil casts,	10′	
Shales; some cherty layers; few thin sandstones, . .	60′	
Concealed strata of unknown character, ...	20′	
Shales; with thin red sandstone layers, ...	50′	210′
Shales greenish; and sandstones calcereous, . . .	30′	
Bossardville limestone, blackish, slaty fracture, full of calcite streaks, ...	40′	
Poxono Island shales (Salina) buff, gray, greenish, calcareous, variegated with red near the bottom, . . .		225′

It appears then that in New Jersey after the laying down of the Bossardville limestone there took place deposit after deposit of limestone, produced by a vast profusion of animal life, shells, corals, sponges, etc., to a height of 363′, before the invasion of the coarse Oriskany sand which only sufficed to make 50′ more. But at the Lehigh Water Gap, after the Bossardville limestone had been deposited the sand deposits immediately commenced, mixed with an abundance of mud and with an almost entire absence of animal life; and this continued for 170′, when the coarse Oriskany sand began to be deposited, and that in such quantities as to make 200′ feet of rock. We will see in the chapter on the middle Juniata region in Mifflin and Huntingdon counties, a great thickness of such sandy shales underneath the Oriskany which there have received the name of *Oriskany shales;* a name which might be applied to the 170′ of sandy shales at the Lehigh Water Gap.

There is even a strong indication of this analogy in the reddish sandstone layers here; for the Oriskany shales of the Juniata hold a series of red beds.* It is admissible therefore to say that the Stormville limestone and lime shale strata which would naturally at the east end of the line be included in No. VI gradually change their character going west, lose their fossils, and assume a No. VII aspect at the Lehigh.

We might go one step further and say that in the 60 miles of our outcrop line we have evidence of a change in the depth of the sea, that the water was shallower at the east end where the animals grew, and deep at the west end where they could not grow, the deep water receiving nothing but mud and sand. This is Prof. White's view; and it is certainly supported by the facts narrated in preceding chapters on Formations No. V and IV, where it has been shown that these formations thin toward the Hudson river and disappear, letting the limestone of VI rest upon the slates of No. III; especially seeing that this non-conformability of VI upon III continues around the great semicircle of the Hudson and Mohawk valleys, and is therefore a phenomenon on a grand scale, a phenomenon hardly explainable unless on the supposition of dry land in that diection, and consequently shallow water off shore. The enormous fecundity of the Mohawk outcrop in animal life gives additional strength to the argument.†

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*If we add 200′ and 170′ together we have 370′ for the thickness of the Oriskany at the Lehigh Water Gap; and if we add the 50′ Oriskany to 315′ Stormville and Decker's ferry beds at Walpack bend we get 365′; so that the total amount of deposited matter at the two localities is almost exactly the same in spite of the difference in quality.

†This apparent intimate relationship of the two formations No. VII and VI can be used as an efficient argument by geologists who amuse themselves with names of classification in discussing the question whether the Silurian system should be made to end at the top of No. VI or at the top of No. VII as Professor Dana prefers; for if a part of No. VI can change in 60 miles so as to become an indivisible lower member of No. VII, the two formations ought to be included in the Silurian system. But on the other hand, as has been said already, the limestone deposits under No. VII repeated themselves or were continued over No. VII, and where No. VII is absent actually formed a continuous series together; so that the lower part of No. VIII might as well be included in the Silurian system. Such a dis-

No. VI on the Delaware river.

The subdivisions of No. VI on the Delaware river are thus described by Prof. White in his report G6 on Pike and Monroe counties.

Stormville shales.—These ashen-gray lime shales, often quite cherty, sometimes contain enough lime to make bastard limestone. They are finely exposed in the gap at Broadhead creek and along the face of Godfrey's ridge just north of the village of Stormville at the east line of Hamilton township, Monroe county, where they measure 160′; and their uppermost layers abound in *Spirifera macropleura*, with other fossils. At Carpenter's Point where these shales are about 150′ thick and sparingly fossiliferous they are capped by a very remarkable group of limestone layers 5′ to 10′ thick called by Dr. Barrett of Port Jervis *the trilobite ledge* containing a great number of species of shells also many of which are unknown elsewhere. The trilobite ledge is full of the head and tail pieces of three species of *Dalmanites*, as described further on in chapter LXXIII on the fossils collected by Dr. Barrett near Port Jervis, and the fossils of the formation in general.

Stormville conglomerate.—These beds of alternate quartz pebble rock and pebble limestone are well exposed immediately under the shales around Stormville thus:

The Stormville Section (G6, 133).

Sandstone, calcareous, with many small quartz pebbles,	10′	47′ 6″
Conglomerate of small pebbles, very hard,	2′6″	
Limestone, pebbly,	5′	
Limestone, sandy,	5′	
Limestone, full of *Pentamerus galeatus*,	10′	
Limestone, sandy, with many quartz pebbles,	15′	

This is a very interesting section, because in the first place the conglomerate does not appear at Carpenter's Point; and at Walpack bend is only 5′ or 6′ thick; at Broadhead creek

cussion is of no importance to the field worker in geology, but possesses a high interest for palæontologists. Professor Hall was led to place the Oriskany beds in the Silurian system because he found fossil forms supposed to be characteristic of No. VI in beds which were recognized as belonging to No. VII.

it is 15′, well exposed under the bridge below Experiment mills; and further west we see quartz pebbles, similar to those of the conglomerate, in the underlying limestones; thus giving us an intimation of the date at which the sandy material began to deposit; for the underlying limestone east of Broadhead creek is destitute of these pebbles; indicating that along the Aquanchicola this conglomerate becomes part of the Oriskany; and may be called its first appearance.

Stormville bastard limestone.—In the Stormville section only the upper layers of the limestone are shown along the Delaware in Monroe county. This group of massive bastard limestone beds measure from 75′ to 100′ and rests upon the Poth-stone cement bed. They are very fossiliferous, *Pentamerus galeatus* being especially numerous at the top of the group, while large corals, *Stromatopora*, *Favosites*, *Receptaculites*, etc. are very abundant near the middle. We have therefore in this group Pentamerus beds and Stromatopora beds for comparing it with any subdivision of No. VI in New York or middle Pennsylvania.

South of Port Jervis the group is 145′ thick, the lower portion extensively quarried at Bennett's in New York and Nearpass' in New Jersey; and here Dr. Barrett has obtained a large number of species. From Walpack bend westward it makes the bold cliffs which rise to a height of 300′ or 400′ above the Delaware river, each layer 10′ or 20′ thick dipping steeply towards the river; and here in the middle group is seen the *Stromatopora* twelve foot bed of the Nearpass quarry section given on page 919 above. In the main these limestones are gray, crystalline, and usually too silicious to burn, and therefore never quarried where the Bossardville (100′ below it) can be used; but its lower beds are very good lime at LeBarr's quarry in Smithfield. Three analyses from this quarry gave the following results:—Carbonate of lime, 90.8, 89.8, 92.3; carbonate of magnesia, 1.2, 1.5, 1.4; oxide of iron and alumina, 0.7, 0.9, 0.6; Sulphur, 0.04, 0.06, 0.09; phosphorus, 0.005, 0.015, 0.006; insoluble residue, 6.8. 7.0, 5.5. A sample of the rock taken from the vicinity of Decker's Ferry (Walpack bend) gave:—

97.1, 1.5, 0.3, 0.018, 0.009, 1.2. A sample taken from one of the beds near Stormville gave :— 74.9, 2.2, 2.6, —, 19.7. The insoluble residue in the last named specimen was also analyzed and found to consist of silica, 16.54 ; oxide of iron and alumina, 0.88 ; lime, 0.08; magnesia, 0.19 ; which seems to illustrate the way by which these sandstone beds gradually get changed westward into lime shales and finally into shaly sandstone ; for we find in this lime rock one-sixth of its substance composed of quartz. Following the outcrop, by the time we reach the Carbon county line very few solid limestone layers are left in the series ; and none at all can be discovered in it at the Lehigh Water Gap.

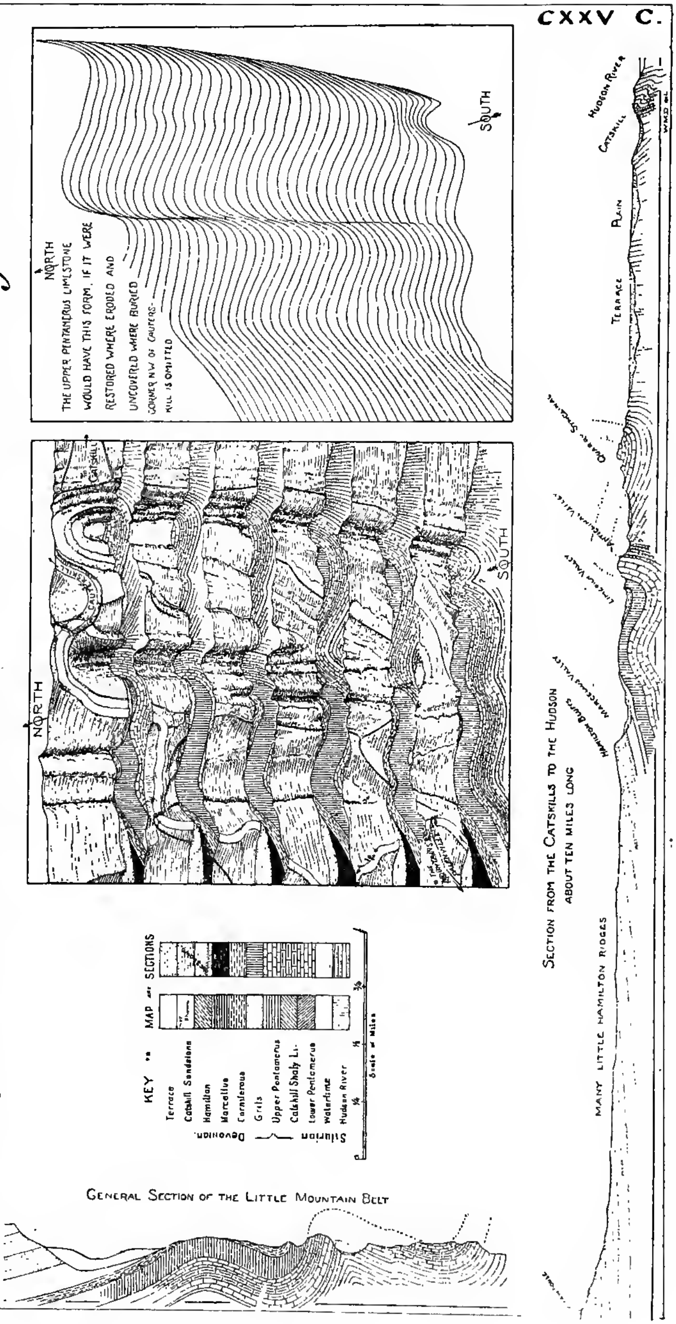
Another important aspect of this group is afforded by the fact that some of its beds contain a good deal of chert ; a chert resembling that in the *Corniferous Limestone Group overlying No. VII;* and these cherty layers are so persistent that they are about the only portion of the Stormville beds as a whole which can be reconized at the Lehigh river *underlying No. VII.*

Stormville (*Peth-stone*) *hydraulic cement bed.*—This seems to have a continuous outcrop from New York, through New Jersey, along the Delaware, and along Godfrey's ridge, westward, to beyond Stormville ; but it is seldom more than 5′, although occasionally 10′ thick. Its color is usually a pale buff ; it breaks with the characteristic earthy fracture of hydraulic limestone ; and is quite destitute of any remains of animal life ; its advent having apparently destroyed a large amount of shell life, for the beds just under it contain millions of *Leperditia alta.* The outcrop of the bed may be seen at many places in the river bluffs from Decker's Ferry westward.*

*No attempt has been made to manufacture hydraulic cement from any place along our outcrop; but as the bed at Decker's ferry (specimen 1) and at DeWitts (specimen 3) is 10′ thick, some of it would probably be found available for this purpose. It probably represents the famous Water Lime bed at the cement quarries at Rondout, Kingston and Rosendale, in the Hudson river valley, resting there however directly upon Medina sandstone No. IV. See Prof. W. M. Davis' description of the Little Mountains east of the Catskills, in Appalachia, Vol. III, No. 1, with maps and sections which I reproduce in fac-simile, on a reduced scale, in plate CXXV, C.

CXXV C.

No. VI nonconformable on No. III at Catskill on the Hudson. Prof. W. M. Davis.



Analysis of two specimens from Decker's Ferry, two from DeWitts in Middle Smithfield township, and one from Stormville, Hamilton township, gave the following composition:—Carbonate of lime, 38.9, 36.4, 37.7, 37.1, 43.8; carbonate of magnesia, 23.7, 17.5, 25.3, 26.4, 29.7; oxide of iron, 3.4, 3.3 †, 3.4, 2.6; aluminia, 4.2, 7.7 ‡, 3.7, 3.7; insoluble residue, 27.4, 28.7, 29.7, 28.5, 17.6. The first and third specimens gave sulphur, 0.065, 0.0113; phosphorus, 0.038, 0.027. The insoluble residue in each of the above analyses gave:—Silica, 24.1, 33.9, 24.8, 24.0, 13.6; oxide of iron and alumina, 2.5, 2.7, 2.4. 2.7, 2.0; lime, 0.2, 0.1, 0.3, 0.1, 0.1; magnesia, 0.4, 0.2, 0.5, 0.2, 0.1 (G6, 136–137).

Decker's Ferry limestone (*Leperditia alta bed*).—Millions of this little fossil shell so abundant in the Landisburg Sandstone of the Middle Salina in Perry county, middle Pennsylvania (F2, p. 54), are imbedded in the upper surface of a bluish gray limestone, usually brecciated, often slaty in its lower layers and more or less sandy, about 20′ thick, lying immediately *under the cement bed* last described. At this horizon in the series of No. VI and at no other in the whole district did Dr. White find the *Leperditia alta*.

It is especially noteworthy that at the horizon of the Decker's Ferry limestone a peculiar iron ore has been mined to a small extent, from 5′ to 8′ above the Decker's Ferry sandstone (next to be described), near Saylorsburg, Ross township, Monroe county, where the sandstone makes a prominent little ridge upon the surface of the ground just south of the ore pits.

The Saylorsburg "flat" ore consists of a number of thin layers of brown hematite, standing vertical, which have been explored to a depth of 50′. Another pit, within ¼ of a mile, 38′ deep, yielded a considerable body of silicious bomb-shell iron ore and impure ochre; but its distance above the sandstone is here 75′. Specimens from the deeper pit

† Dr. Beck's old analysis of this gave, carbonate of lime 48.4, carbonate of magnesia 34.3, silica and alumina 13.8, peroxide of iron 1.7, water and loss 1.7.

‡ In the third specimen the oxide of iron and alumina were calculated together making 6.3.

give: Iron 4.15, 39.4; sulphur 0.030, 0.007; phosphorus 0.3, 0.3; insoluble residue 23.5, 26.7. Specimens of ore from the ochre pit gave:—Iron 29.1. 30.0, 31.4; sulphur 0.01, 0.01, 0.01; phosphorus 0.11, 0.8, 0.18; insoluble residue 44.0, 27.9, 38.4. The ochre interstratified with the ore gave: Silica 57.40, alumina 19.03, sesquioxide of iron 10.11; lime 0.10; magnesia 1.74; water 6.46 (G6, 138, 139).*

Decker's Ferry sandstone.—This little group of gray limy sandstone, sometimes charged with small quartz pebbles, and crowded with fossil shells, among which may be designated the small *Chonetes* and a large *Avicula* with wavy margin, may be seen in a low cliff just above the road leading southwest from Decker's Ferry; frequently along the river from Decker's Ferry to the Water Gap; in a bold

*It has been suggested that these ore deposits are a surface formation, resulting from the decomposition of the Oriskany sandstone outcrop running along on their northern side. A similar suggestion was made fifty years ago by Dr. R. M. S. Jackson of the First Geological Survey, in regard to the brown hematite deposits of Kishocoquillas and especially Nittany valleys; but all succeeding investigations have opposed, and effectually put an end to that suggestion. In the present case such a suggestion is equally inadmissible. We have an overwelming mass of evidence that all our brown hematite iron ore deposits, large and small, are the result of the decomposition of strata whose outcrops cross the ore banks. All iron-bearing lime shales will moulder down in the lapse of ages into brown hematite and ochre deposits. The ochre beds of Saylorsburg are evidently nothing but the mouldered layers of Stormville lime shales: and Professor White noticed as a common occurrence that a coating of ochre adhered to the weathered surfaces of many of the limestone layers in No. VI. The vertical attitude of the layers of "flat" ore are also a proof that the iron has not been brought from a distance, but manufactured by nature on the spot. It happens indeed that the Oriskany sandstone at Saylorsburg has also itself been broken down by the weathering process into a great bed of loose white sand and clay, but whatever iron it possessed has no doubt been carried to a distance. The cause of the breaking down of the Oriskany into sand here (as at McVeytown, Mifflin county, on the Juniata) should not be looked for in the ferriferous character of the formation, but rather in the fact that it was not all ferriferous, that in fact the rock had not enough iron to cement its grains solidly together. This however leads us to another and very different hypothesis of the origin of the underlying iron ore strata. It suggests that while the formations were still beneath the sea and in a wet condition lying horizontally whatever iron the Oriskany contained passed downward and was retained by the underlying Stormville shales; which, thus more heavily charged with iron than they otherwise would have been, when the continent rose, and the beds were thrown into a vertical position, allowed the weathering of the shales and the concentration of the ore beds.

cliff one mile north of Water Gap Railway station; in the hill above the Experiment Mills limestone quarry in the field just above the stone house at Stormville; and at the Saylorsburg iron ore diggings. It seems to be a persistent member of No. VI;* and to be represented at one of the limestone quarries 1½ miles above the Lehigh Water Gap by a massive greenish limy sandstone, *without pebbles*, from 20′ to 30′ thick; but it does not seem to extend through New Jersey into New York, not being noticeable in the Port Jervis quarries. *Its fossils* are very poorly preserved, the shells having been in most cases dissolved away, merely leaving their casts in the rock. At Experiment Mills at Broadhead's creek the stratum stands like a massive wall 10′ or 15′ high. At Stormville it dips 75° (N. N. W.); at Saylorsburg it averages 15′ and is sometimes 25′ thick.

Decker's Ferry shale.—Under the sandstone last described are exposed a group of greenish gray lime shales about 15′ thick, which seems to extend along the whole Monroe and Carbon county outcrops; being in some places a green shaly limestone; and it may perhaps be the 10′ of greenish shales and shaly limestone in the Nearpass quarry section given above lying upon the massive Chaetetes limestone of New Jersey. *A cement bed*, 5′ thick, occurs apparently at this horizon near J. DeWitt's at the river bluffs (several miles below Decker's Ferry) in the following section, (G6, 221):

J. De Witt's section.

Stormville shales,	visible 30′
Stromville conglomerate,	20′
Concealed strata,	65′
Limestone, massive, fossiliferous,	25′
Concealed strata,	10′
Hydraulic cement beds,	10
Limestone, brecciated, bluish, fossiliferous,	10′
Shaly limestone, partly concealed,	20′
Decker's Ferry sandstone and shale,	35′
Water lime, impure,	5′
Bossardville limestone,	60′

Bossardville limestone.—All the large limestone quarries of Monroe county are in this rock, which practically furn-

* Compare the curious isolated sandstone beds occasionally seen in the body of the great limestone formation No. II.

ishes all the lime burned in the county; the most extensive of them being at Bossardville in Hamilton township, north of the Wind Gap.

Its top beds come out of the Delaware river just above Decker's ferry at Walpack bend and it is quarried at the roadside on a bluff west of the ferry. The section here is as follows:—

Decker's Ferry section (G6, 218).

Stormville shales, very fossiliferous, ... visible	20′	205′
Lime shales, cherty, with some pebbles, fossiliferous, . .	35′	
Pebbly layers, ...	5′	
Stormville limestone, very massive, gray, visible, .	20′	
Concealed strata (probably limestone), . .	75′	
Deckers ferry sandstone, limy quartz pebbles, many fossils,	20′	
Decker's ferry lime shales, gray, ...	15′	
Bossardville limestone, slaty fracture, visible, . . .	15′	

Here (in Grube's quarry) the thin layers of bluish gray rock breaking with a slaty fracture are entirely without fossils, except some minute forms which look like *Beyrichia*, and some small indistinct fragments. At Van Auken's quarry a mile below, the D. F. sandstone (25′) is 100′ above the river and the Bossardville limestone is concealed. But at J. C. DeWitt's a mile further down the river, the Bossardville limestone is exposed beneath the sandstone (20′) in a vertical bluff 60′ thick, and more beneath the water; the upper portion bluish gray; the middle and lower bluish black traversed by veins of calcite; the submerged bottom showing through the water the banded structure peculiar to the columnar beds. At the school house further west the sandstone (30′) is 40′ above the river, but the limestone concealed. At DeWitt's (1½ miles below the school house) under the sandstone (with shale 35′) the Bossardville limestone, extensively quarried, shows for 65′; the top 5′ is bastard hydraulic cement; upper layers gray; body of the mass bluish black, with much calcite in irregular streaks and veins. Further down the river, opposite the upper end of Poxono island we see the Bossardville limestone fully exposed in Turn's steep bluff and terrace (G6, 223):

Poxono Island section.

	Stormville conglomerate,	25′	215′
	Bastard limestone, massive	75′	
	Concealed strata,	40	
	Bossardville limestone,	75′	
Salina No. V.	*Poxono shale,*	200′	330′
	Poxono limestone, bluish gray, crystalline,	5′	
	Green shales,	5′	
	Red shale,	5′	
	Concealed strata down to water level,	45′	

This section is of the highest importance, because this is the only place along the whole line of No. VI from New York to the Lehigh Water Gap, where the relation of the Bossardville limestone to the *Salina red shale* can be seen. Not a single exposure of this interval can be found in New Jersey; which explains the want of harmony between Professor White's section and that given in the New Jersey reports. For this fortunate exposure we are indebted to the deep little ravine which a small stream of water has cut through the nearly vertical bluffs, laying bare almost all the shales which underlie the Bossardville limestone. It gives us also the actual full thickness of the limestone along this part of the outcrop.

Bossardville Limestone, Upper Division.—The Bossardville limestone is separable into two well marked divisions; the upper or quarry portion is usually say 65′ thick; has a prevailing dark color sometimes almost black, but the top beds are generally gray or bluish gray. The dark rock is traversed in all directions by seams of calcite, white crystalline limestone, breaks with a very sharp angular fracture; has a thin flag-like bedding; and is entirely non-fossiliferous, if we except minute dark specks, which may be the shells of the little *Beyrichia.*

At the New York state line the bottom layer seen in Nearpass' quarry (given on page above) has all the character of the Bossardville limestone but is only 3′ thick and everything underneath it is concealed, which leaves the identification uncertain.*

*The outcrop along the Delaware river, so satisfactory for its numerous and good exposures, contrasts strongly with the outcrop along Godfrey's ridge west of the Water Gap, because here it is covered up by the *débris*

The Bossardville quarries

The great quarries at Bossardville yield several hundred thousand bushels of lime per annum which is hauled far and wide into the surrounding country. The stone burns readily to a light gray lime not white enough for plaster but much valued for farm and building use (G6, 282). At Heller's quarry, which is the largest, the rock runs in cliffs 40′ and 50′ high above the road. The output of the kiln is about 100,000 bushels per annum, selling from 6 to 8 cents at the quarry. Here the thin dark blue layers are much contorted and show no fossils. At Featherman's quarry a bluff of dark blue slaty limestone with veins of calcite rises 35′ above the creek. From the Bossardville quarries westward the outcrop is again continuously concealed beneath a copious covering of sand from the Oriskany ridge, and might be found anywhere by sinking through this local drift. The outcrop re-appears in front of the Wind Gap, west of Saylorsburg in Ross township. At Lessig's extensive quarries it is not so thick as usual nor so pure; and the pressure to which it has been subjected, as shown by the crimpling and folding of the beds, has given it a slaty cleavage, which is an interesting fact. From Lessig's to Kunkletown it is again covered with local drift; then comes to the surface and is quarried and burned extensively; its beds so much twisted and contorted that no dip can be obtained.

Its thickness on the Lehigh, in the railroad cut, one mile below Bowman's station, is only 30′ or 40′; but its character is there the same.

Analyses of the Bossardville quarry beds were made from samples taken at the Bossardville quarries (1,2); from Van-Auken's quarry (3, 4, 5, 6,), and from Brown's quarry (7.8)

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shed from the steep slope of the ridge down upon the northern slopes of Cherry valley. The common belief of the farmers is that there is no limestone along the valley; but this must be a mistake; and no doubt the outcrop could be exposed on every farm by merely sinking shafts through the surface drift, and quarries might be opened along the whole line. The popular impression has been so strong that no attempt to find it has been made from the quarry near Experiment Mills on Broadhead's creek for five miles west to the quarry one mile west of Stormville.

in Smithfield township, Monroe county; as follows: Carbonate of lime 94.3, 87.9, 82.7, 93.3, 93.9, 88.8, 94.3, 92.2; carbonate of magnesia 1.5, 1.9. 2.8, 1.4, 1.3, 2.3. 2.1, 2.2; oxide of iron and alumina 0.7, 2.1, 1.4, 0.8, 0.7, 0.7, 0.5, 1.1; sulphur 0.1, 0.2, 0.7,* 0.1; 0.2, 0.2, 0.2, 0.2; phosphorus 0.014, 0.019, 0.007, 0.010, 0.010, 0.013, 0.015, 0.020; insoluble residue 2.8, 7.9, 11.9, 4.2, 3.9, 7.6, 3.0, 4.3; see analyses to three figures of decimals on page 142 of Report G6.

The Bossardville Limestone, Lower division.—This may be called 25′ thick at the quarries, and differs greatly in aspect from the overlying quarry beds; having a dark gray color and a peculiar banded or *ribbon* appearance, produced by the edges of very fine layers of different colors, gray, whitish, blue, etc. evidently mud deposits in very still water at regular intervals, perhaps governed by seasons, and sorted according to fineness and weight by the different rates at which the particles find their way downward to the bottom.† It also possesses a genuine *columnar* structure, which is finely exhibited at Experiment Mills quarry on Broadhead's creek opposite the Delaware Water Gap, the rock possessing a prismatic structure like the basaltic columns in lava; but not throughout the whole 25′; but confined to certain beds, the one exhibiting it most decidedly being 3′ thick and 7′ above the base.‡

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* Average of two determinations.

† Vanuxem reports that some of the Water lime beds in Middle New York have this ribbon structure.

‡ In the Niagara formation of western New York and Canada, the columnar structure is quite common.—This columnar structure is still more curious considering the fact that the columns (Stylolites) are inclined to the southeast at the angle of 75° while the dip of the bed is in the same direction and only 35°; therefore not at all at right angles to the bedding (as basaltic columns always are); and thus probably produced by pressure; in which case we must consider the phenomenon as coming under the head of cleavage. The same structure is seen just below the falls at Shawnee in Smithfield township; but the beds in which it occurs lie higher in the series; and answers perfectly to Professor Cook's description of the *ribbon limestone* found at the base of the series along the New Jersey outcrop. Many of the layers in the Stormville limestone (described above) often possess this ribbon aspect, Analyses of the columnar limestone from Experiment Mills gave:—Carbonate of lime 73.428, carbonate of magnesia 2.648, oxide of iron

The non-fossiliferous character of the entire mass of Bossardville limestone along the whole line of outcrop, is a very curious phenomenon, if the deposit is to be accounted one of the Lower Helderberg series.*

Poxono Island shales.—This group, at first included in No. VI, has been now adopted as the top of the *Salina division of No. V.* Under the Bossardville limestone come buff, greenish gray and variegated lime-shales, nowhere well exposed along the whole line of outcrop except at the one place, in the little ravine opposite Poxono island in the Delaware river. They are partially exposed where the eastern line of Smithfield township comes to the river; and the top beds are seen at Experiment Mills quarry on Broadhead's creek; also, on the Kem-

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and alumina 2.970, insoluble residue 20.240; from which analysis it may be inferred that the rock might make a fair hydraulic cement and it is reported that a very good cement was once experimentally made from it at the Bossardville quarries (G6, 282).

* Dr. Barrett claims to have found the characteristic Niagara fossil *Halysites catenulata* in the quarries south of Port Jervis; and other Niagara forms in the lower beds of the Nearpass' section, page 919 above. In the first survey 50 years ago it was taken for granted that these lower beds of No. VI in New Jersey, represented the Niagara formation thinning out as its outcrop entered Pennsylvania at Walpack bend; nor did the geologists of the first survey recognize the existence of the Niagara formation anywhere in middle Pennsylvania. It has been shown in the last chapter on Formation No. V, that the only possible appearance of a Niagara limestone outcrop is that at Barree forge on the Upper Juniata in Huntingdon county described in the report at (T2, 132); but the Niagara character of that local Barree-limestone-group is there indicated only by the presence in it of *Favosites niagarensis;* no other Niagara fossil form having been found in it. Whatever Niagara fossils have been found in Pennsylvania have been found mixed with the Clinton, Salina and Lower Helderburg fossils. Eastern Pennsylvania should be the last place to look for the Niagara formation, seeing that its great development was in Canada and western New York; thinning eastward into eastern New York and disappearing entirely in the Hudson river. Vanuxem asserts that not a trace of it is to be seen east of the village of Mohawk in Herkamer county. If therefore Niagara fossils are found in the Port Jervis quarries they ought not to be taken as a proof of the extension of the Niagara formation that far east and south; they merely show that the creatures which lived before Salina times in the northwest, continued to live after Salina times in the southeast; a fact which adds one instance more to the mass of evidence we have that the service of fossil forms for classifying a series of deposits according to age avails only within restricted geographical limits and will always and necessarily fail us for universal deposits.

merersville road one mile west of Stormville ; also at Featherman's falls of Cherry creek near by. Their characteristic buffish gray color is often tinged with greenish white, and has thin streaks of red. The beds are more or less magnesian, and are without fossils. The whole series measures probably more than 200′. At the Lehigh water gap 225′ of them are well exposed by the N. J. Central railroad cuts, one mile below Bowman's station, standing vertical, with beds of red shale thicker than on the Delaware.*

Poxono (*Beyrichia*) *limestone.*—This bed, only 5′ thick, hardly deserves a special name, because it has been recognized at only the one exposure, in the ravine opposite Poxono Island, underneath the shales last described ; if persistent for any long distance the fact cannot be ascertained, because its outcrop is everywhere else covered. It is however important as a fossil horizon, being full of the small *Beyrichia*, and of fragments of shells of other species, all of them also small, and none of them recognizable. The rock is nearly a pure limestone, as shown by two analyses ; Carbonate of lime 90.2, 89.4 ; carbonate of magnesia 4.3, 3.3 ; oxide of iron and alumina 1.1, 1.3 ; sulphur 0.3, 0.3 ; phosphorus 0.010, 0.013 ; insoluble residue 3.6, 5.9.

Under the Beyrichia limestone lie greenish shales, 5′ ; and then deep-red shales of great thickness, which we may safely consider *Salina Lower* (*Bloomsburg*) *red shale.* This justifies the classification of the Poxono Island shales as *Salina Upper.*

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* Analyses of three specimens from the Poxono Island exposure show :—Carbonate of lime 20.7, 36.3, 48.4 ; carbonate of magnesia 12.3, 16.2, 27.1 ; oxide of iron 3.9, 3.8, 3.9; alumina 12.4, 7.3, 3.1 ; insoluble residue 42.9, 31.4, 17.2. In the first specimen, sulphur reads, 0.182 and phosphorus 0.044 ; and its insoluble residue, silica 37.2, oxide of iron and alumina 3.3, lime 0.1., magnesia 0.3 (G6, 146).

CHAPTER LXVII.

No. VI in Carbon, Schuylkill, Lebanon and Dauphin counties.

The outcrop described in the last chapter, extending from Port Jervis past the Delaware Water Gap to the Lehigh Water Gap, a distance of sixty miles, on a course about S. 50° W. is continued thirty-five miles further, on a course S. 60° W. to Schuylkill Haven, where a few feet of limestone appears at the surface, brought up on the sharp crest of the great Orwigsburg anticlinal; which sinking westward carries the formation under ground and it is not seen again for 50 miles, until it rises to the surface in Perry county.

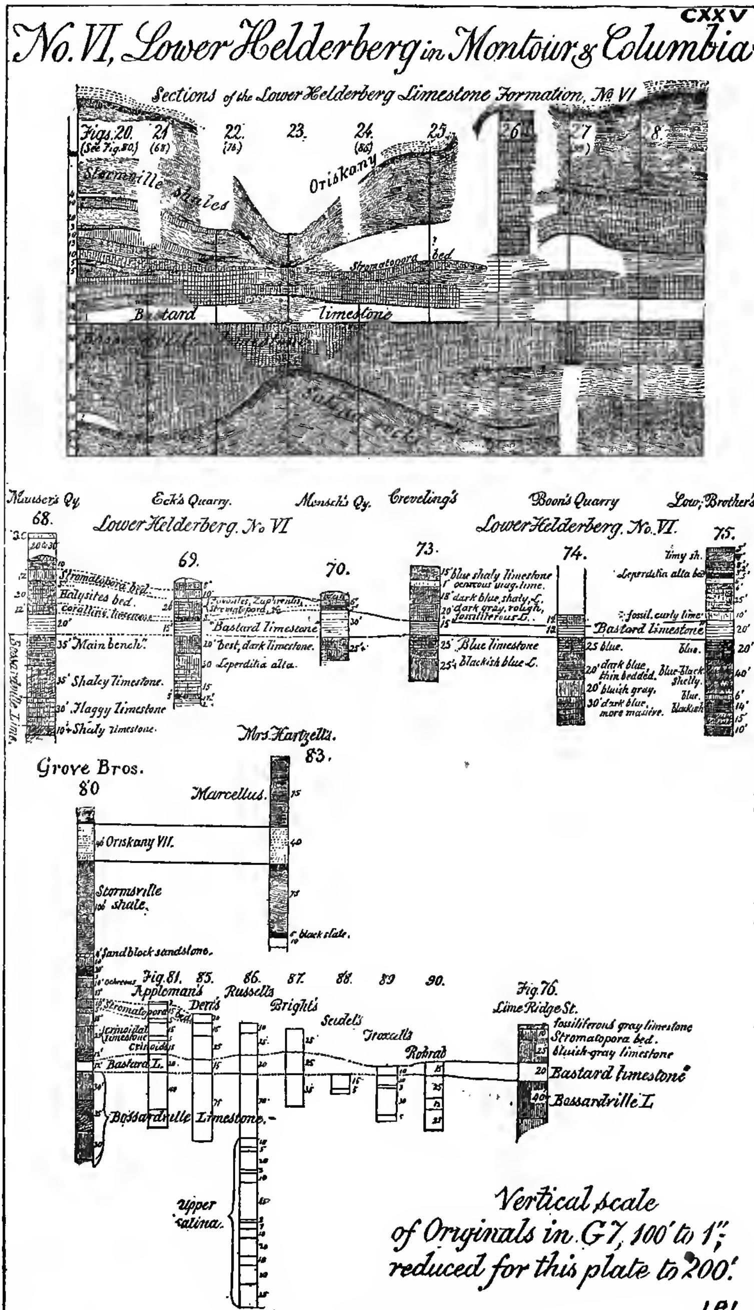
The north dip is vertical and the outcrop perfectly straight. The south dip is about 30°; and its outcrop returns from Schuylkill Haven eastward about eight miles; then makes a sharply zigzaged semicircle southward 5 miles; crosses the Schuylkill below Auburn, and then runs S. 70° W. for 25 miles to the Swatara Water Gap, where a few beds of limestone show themselves dipping steeply northward. From the Swatara to the Susquehanna, 22 miles (S. 55° W.) No. VI is supposed to be absent from the series; also, for 12 miles west of the Susquehanna; when it re-appears at Sterrett's gap, and commences its great zigzags through Perry county, as will be described hereafter.*

Our information respecting No. VI along the whole line of 75 miles from the Lehigh to the Susquehanna is very defective. The Orwigsburg valley between the Kittatinny mountain on the south, and the Second mountain on the north, from river to river, was not well studied by the First Geological Survey; and it has not yet been re-surveyed.

* This disappearance of the outcrop of No. VI, for 30 miles, east and west of the Susquehanna, is an unexplained fact, already alluded to in the chapter on No. V.

No local sections have ever been made along the line. Godfrey's ridge (called the Steinberg at the Lehigh Water Gap) is gapped by the Little Schuylkill at McKeansburg, and runs on past Orwigsburg to Schuylkill Haven. From Auburn westward to the Swatara, the ridge is low and broken ; and it seems to disappear entirely between the Swatara and the Susquehanna. This ridge being made chiefly by the Oriskany sandstone No. VII, by the sandy Stormville shales beneath it, and by the Bossardville limestone at its foot, merely marks the continuance of formation No. VI, but gives little information respecting its internal structure. As there are no limestone quarries of any importance between the Lehigh and the Susquehanna, it is evident that the lower member of the formation gradually loses its importance going southwest.

What the condition of the formation is beneath the anthracite country it is impossible to say ; but we can safely conjecture that it maintains its Delaware river character under most of the region ; because, where it is brought to the surface again on the Susquehanna river, only twenty miles north of the Blue mountain, by the Georgetown anticlinal, in the southern corner of Northumberland county, and again, ten miles further north, by the Selinsgrove anticlinal, and again, six miles further north by the Montour anticlinal, and repeatedly again by the Buffalo mountains and Bald Eagle anticlinals between Sunbury and Muncy, it is in full force. Two bold outcrops of No. VI run along the south and north sides of Montour's ridge as far east as Berwick (where the Luzerne county line crosses the North Branch of the Susquehanna); and Berwick is only 30 miles due north of Schuylkill Haven, 35 miles northwest of the Lehigh Water Gap, and 65 miles due west of Walpack bend. We shall see directly that No. VI on its two Montour ridge outcrops, converging eastward, meeting and sinking at Berwick, is as well developed as in Monroe county, and that its beds bear so striking a resemblance to the beds last described along the Delaware river, that there can be no doubt whatever of the integrity of the formation under the whole of northeastern Pennsylvania.


CXXV
No. VI, Lower Helderberg in Montour & Columbia
Sections of the Lower Helderberg Limestone Formation, No VI
Figs. 20. (See Fig. 80.) 21 (68) 22. (76) 23. 24. (86) 25.
Stormsville shales
Oriskany
Stromatopora bed
Bastard limestone
Mauser's Qy 68.
Eck's Quarry.
Mensch's Qy.
Creveling's
Boon's Quarry
Low; Brother's
Lower Helderberg. No VI
Lower Helderberg. No. VI.
69.
70.
73.
74.
75.
Stromatopora bed.
Halysites bed.
Coralline limestone
35' Main bench.
35' Shaley limestone.
30' Flaggy limestone
10+ Shaly limestone.
Bastard limestone
Best, dark limestone.
Leperditia alta.
15' blue shaly limestone
1' ochreous mag. lime.
18' dark blue, shaly, L.
20' dark gray, rough, fossiliferous L.
25' Blue limestone
25' Blackish blue L.
25 blue.
20' dark blue, thin bedded.
20' bluish gray.
30' dark blue, more massive.
limy sh.
Leperditia alta bed
fossil. curly lime
Bastard limestone
blue.
Blue-Black Shelly.
Blue.
Blackish
Grove Bros. 80
Mrs Hartzell's. 83.
Marcellus.
Oriskany VII.
Stormsville shale.
Sandblock sandstone.
black slate.
Fig. 81. Appleman's
85. Deri's
86. Russell's
87. Bright's
88. Seidel's
89. Traxell's
90. Rohrab
Stromatopora bed
Crinoidal limestone
Crinoids
Bastard L.
Bossardville Limestone.
Upper salina.
Fig. 76. Lime Ridge St.
fossiliferous gray limestone
Stromatopora bed.
bluish-gray limestone
Bastard limestone
Bossardville L.
Vertical scale of Originals in G7, 100' to 1"; reduced for this plate to 200'.
J.P.L.

Chapter LXVIII.

No. VI on the North Branch Susquehanna.

From Berwick on the Luzerne county line westward past Bloomsburg and Danville to the Susquehanna river three miles above Northumberland, a distance of 35 miles, runs a south-dipping outcrop of No. VI along the foot of Montour's ridge. The corresponding north-dipping outcrop, runs from Berwick along the northern foot of the ridge, westward, across Fishing creek, past Mausdale and Mooresburg, to Lewisburg on the West Branch, a distance of 37 miles.

Extensive quarries are opened upon the formation along both these outcrops, and a careful study of it by Professor White, in his Report G 7, furnishes a sufficient number of local sections to prove its resemblance, even in the details of its subdivisions, to No. VI on the Delaware river. The first three sections now given were made along the south outcrop: (1) at Grove Bros.' quarry in Cooper township, at the eastern line of Montour county; (2) at Mauser's quarry near the Montour township line in Columbia county; (3) at the Low quarry near Lime Ridge, in eastern Columbia county. (G 7, Figs. 20, 21, 22 of Plate on page 84.)

No. VI Grove quarry section; S. dip.

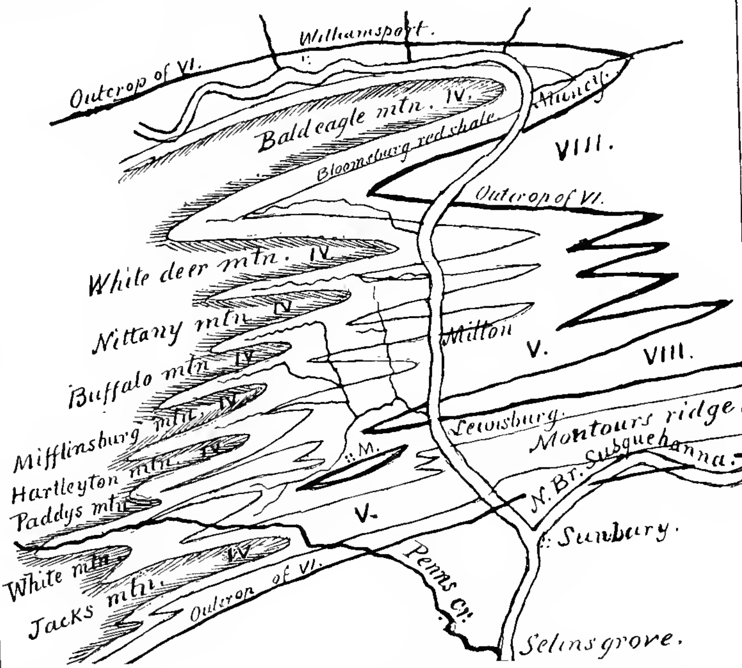
Oriskany Sandstone No. VII.

Stormville shale, a series of blackish and gray shales interstratified with some impure limestones, fossiliferous; containing *Spirifera macropleura*, *Strophomena depressa*, and multitudes of a small flat, branching *fucoid* in some of the black shale beds; thickness, ... 100′

Stormville conglomerate, a very silicious bed (at times nearly a quartzite), called "*Sand block*" by the miners; contains some lime and nearly as hard as granite when it was cut by the Grove Bro.'s tunnel; contains *Spirifera arenosa*, or a form very much like it; thickness, ... 4′

CXXV B.

No. VI. Sketch of zigzag outcrops in Snyder & Union.



Rough sketch copy of J. Hall's specimen.

Diagram section to show connection of Upper & Lower Helderberg corals.

Stormville limestone, good, dark blue,	10′	111′
Limy shales, and shaly limestone,	20′	
Limestone, blue, good,	3′	
Limestone buffish and ochery on its weathered surface, crumbling on exposure,	10′	
Limy shales, and shaly limestone,	13′	
Stromatopora bed, a very hard, tough, bluish-gray limestone, filled with *Stromatopora concentrica*,	10′	
Shaly limestone, bluish,	5′	
Limestone, dark blue, crystalline, rather pure,	15′	
Very massive, somewhat sandy limestone, contains many *crinoidal* fragments,	25′	
Bluish, shaly limestone,	12′	
Bastard limestone, buffish gray, impure, magnesian,	12′	
Bossardville limestone.		
(a) Dark blue and blackish limestone in thin layers, quite pure,	30′	105′
(b) Bluish gray, impure limestone in very thin layers (¼″–1″),	35′	
(c) Bluish, and dark gray limestone rather pure; visible,	30′	
(d) Concealed to top of *Salina No. V*,	10′	

Total of exposed beds of No. VI, 384′.

No. VI Mauser quarry section; S. dip.

Limestone, shaly and flaggy, bluish,	10′	
Stromatopora bed, massive bluish gray limestone, composed almost entirely of *Stromatopora concentrica*,	12′	
Limestone, shaly, bluish,	5′	
Limestone, massive, gray, containing vast quantities of *Halysites catenulata*,	20′	
Limestone, rough, gray, somewhat crystalline; a mere mass of *crinoidal fragments* and broken shells, also containing a form which very much resembles *Cladopora multipora* in large numbers, *Favosites helderbergiæ*, and many other undetermined forms,	12′	
Bastard limestone, a buffish, impure magnesian rock, containing several species of *Beyrichia*, *Strophomena rugosa*, *Atrypa reticularis*, *Rhynchonella formosa*, and other fossils,	20′	
Bossardville limestone.		
Upper beds, flaggy, very pure, very dark, full of thin regularly calcite veins,	about 35′	120′
More shaly flags; vast numbers of *Leperditia alta*,	about 35′	
Purer, dark blue beds,	about 50′	

No. VI Low quarry section; S. dip.

1. Limestone, bluish gray,	5′
2. Shaly limestone, and limy shales,	10′
3. Limestone, bluish gray, shaly,	8′

4. Limy shales, and shaly limestone, . . . 5′
5. Limestone, dark, filled with *Leperditia alta*, . . 5′
6. Drab, sandy, limy shale, ... 6′
7. Dark blue, limy shale, ... 6′
   Stromatopora bed absent.
8. Limestone, bluish gray, massive, rather pure, fossiliferous, ... 35′
9. *Bastard limestone*, ... 20′
10. *Bossardville limestone*, dark blue and bluish black limestone in thin layers, non-fossiliferous, nearly all pure enough for burning into lime; entire thickness down to top of *Salina, No. V*, ... 105′

Analyses of specimens from beds 5, 8, 9, and the upper, middle and lower part of 10, gave the following results, and fairly represent the formation:

	Lime carb.	*Mag. carb.*	*Al. & Ox. I.*	*Phos.*	*Residue ins.*
Bed 5, ...	88.450	4.782	.660	.020	6.260
Bed 8, .	82.371	7.791	1.190	.023	8.830
Bed 9, . .	70.981	5.630	3.440	.032	19.510
Upper 10, .	92.314	3.901	.530	.006	3.340
Middle 10, .	96.125	1.767	.500	.006	1.820
Lower 10, .	94.267	1.934	.550	.020	3.480
Lower 10, . .	93.378	2.004	.630	.014	4.170

Two additional sections were made on the northern outcrop; one on Fishing creek, 2½ miles above Bloomsburg; the other at Russel's quarry, on Mahoning creek, two miles north of Danville (Figs. 23, 24).

No. VI. Fishing Creek section; N. dip.

Black slates and dark shales, ...	65′	210′
Stormville shales, ash-colored, limy beds on top, . .	35′	
Limestone, shaly, gray, ...	20′	
Limestone, sandy, ...	10′	
Lime shales, drab, ...	30′	
Bossardville limestone, bluish black, somewhat shaly and flaggy, ...	50′	
Salina, No. V.		

No. VI. Russell quarry section; N. dip.

Stromatopora bed, ...	10′	125′
Limestone, hard, blue, fossiliferous, . .	25′	
Bastard limestone, ...	20′	
Bossardville limestone, blue-black, thin layers no fossils; blue-gray toward the bottom, ...	70′	
Salina No. V.		

The incessant and often considerable variation in thickness and character which the beds of No. VI undergo along their outcrops, and also no doubt under the entire region of northeastern Pennsylvania and southern New York, is exhibited very well by the difference between the three southern and two northern of these five sections, along outcrops meeting at Berwick, and nowhere more than three miles apart. So far as sections can be obtained by which to ascertain the fact on the southern side of the arch the quarry-limestone subdivision is better developed than on the northern side of the arch. Considering the broad summit and gentle dip on both sides of the arch it is hardly possible that this difference was caused by the side pressure which raised the arch ; it must be an original difference of deposit. But the northern outcrop is not so well exposed and cannot be so thoroughly examined as the southern out-crop. There must be and no doubt are great variations east and west, commensurate with the differences noticed in passing from the south to the north side of the arch. In fact, along the northern outcrop, from Berwick to opposite Danville, the quarry-limestone is so poorly developed that only half a dozen quarries have been opened on it ; but, from opposite Danville westward it begins to thicken ; and considerable quarries have been worked on it between Mahoning creek and Lewisburg.

At Lewisburg on the West Branch the north dipping outcrop sinks beneath Formations VII and VIII, to rise again (with a south dip) three miles further up the river ; the two lines of outcrop converging westward in Union county, and meeting on Buffalo creek four miles west of the river. This south-dipping outcrop runs east 10 miles into Montour county ; then zigzags northward for three miles ; and then returns (as a north-dipping outcrop) 10 miles to the river above Uniontown.

The extreme east point of the central zigzag is at Washingtonville (10 miles east of Milton) where the zigzags broaden the surface exposures of the formation, and give occasion to numerous quarries. The southern outcrop is called Limestone ridge, and the following section was obtained where a small stream makes a little gap on the northern line of Liberty township, Montour county.

No. VI. Limestone Ridge section.

Oriskany sandstone No. VII.		
Stormville shales, dark and ashen gray,	75′	280′
Concealed strata,	40′	
Stromatopora bed, massive,	10′	
Lime shales and shaly limestone,	15′	
Limestone, massive, gray, fossiliferous,	25′	
Bastard limestone,	15′	
Bossardville limestone, dark blue and blackish, thin layers, . . . visible,	75′	
Concealed strata, probably the same,	25′	
Salina No. V.		

Along the north-dipping outcrop from Washingtonville to Uniontown, no detailed section could be obtained ; but numerous imperfect exposures at several horizons seem to show that the whole series is not so thick, and does not contain such good limestone. This outcrop line crosses the river and runs five miles (west) into Union county up White Deer Hole ; then turning sharply in the axis of the trough to a south-dipping crop it runs straight E. N. E. diagonally across the river to Hughesville in Lycoming county, three miles east of Muncy. Here it turns sharply back over the axis of the Bald Eagle anticlinal, and begins its long course westward and southwestward past Williamsport and Lock Haven to Altoona in Blair county ; as will be described in another chapter.

Stormville series along Montour's Ridge.

The Stormville shales in the Grove quarry section given above and strictly included between the Oriskany sandstone and Stormville conglomerate are 100′ thick. The *Stromatopora* bed is here 160′ beneath the Oriskany. In the Limestone ridge section 75′ of shales are seen ; and 40′ further down comes the *Stromatopora* bed, here only 115′ below the Oriskany. In the Fishing Creek section these shales appear to be only 35′; but perhaps we ought to include the overlying black slates ; in which case they will measure 100′. Here however there is no Oriskany to measure from.* On Fishing Creek the shales are actually seen thinning from 15′ to 2′ in a distance of only 40′ (G7, 230); and there seems to be no mistake about this extraordinary decline, because here (at the limestone quarry just below the slate works) the Oriskany seems to be represented by a bed of sandy chert 6′ thick holding its characteristic fossil *Spirifera arenosa.* This bed lies directly upon the shale and the shale lies directly upon the massive limestone beds (G7, 226). We may however regard the *usual* thickness of the shales as about 100′; sometimes nearly the whole mass is of an ash-gray color; sometimes much of it is dark brown or nearly black; with interstratified thin shaly impure limestone layers.; and layers of chert.†

Fossils are generally present, but seldom abundant; chiefly *Spirifera macropleura* and *Strophomena depressa.* The black or dark shales, when present as in the Grove tunnel, always hold a flat ribbon-like branching *fucoid* resembling *Buthotrephis gracilis.*‡ As no Oriskany fossils are seen the Stormville shales fall naturally into No. VI.

Stormville conglomerate (*Sand block*).

In the Grove quarry, at the line of Montour county (see section above) an exceedingly hard 4′ bed of a very silicious-calcareous sandrock appears 100′ below No. VII,

*The black slates are here immediately covered by 20′ of dark, hard sandy slates, exactly resembling the *Cauda Galli beds* which overlie the Oriskany in Pike and Monroe counties (G7, 219).

†It is possible that the 6′ chert bed is one of these; in which case there is no exhibition of the Oriskany sandstone at all in the section; but in the next paragraph it will appear that a spirifer like *Spirifera arenosa* occurs in the *Stormville conglomerate* 100′ beneath the Oriskany, at the Grove quarry. This illustrates the impossibility of making a classification which will hold good everywhere; but it also throws doubt on the extraordinary thinning away of the *Stormville shales* asserted in the text.

‡The sub-Oriskany (*Stormville*) shales crop out in Montour county, east of Danville, along the north side of a sharp low ridge, and are exposed on a road: ashen-gray slaty beds, becoming blackish in the lower layers 75′, black slate 5′, gray shales 10=total visible 90′. It is possible that the original color of the whole mass was black or blackish and that the gray beds have been bleached. Most of the Oriskany (here 40′) is a blackish, cherty, limy rock like the Corniferous on the Delaware, and the true Oriskany may be absent (G7, 306).

which is exactly the horizon of the Stormville conglomerate on the Delaware river. The miners who drove the tunnel reported it as hard as granite. On the weathered outcrop the lime dissolves out, giving the rock the look of a coarse porous sandstone; but elsewhere the outcrop resists weathering and looks like chert or quartzite. Casts of a large coarse *Spirifer* may be found in it which seems to be the characteristic *Spirifera arenosa* of the Oriskany No. VII. It can be traced a mile or two E. and W. of the county line.*

A cherty limestone bed (4 to 5′ thick), holding *Spirifera arenosa*, appears on Appleman's run, between the quarry and the road, directly under the shales. (G 7, 247).

Stormville limestone along Montours Ridge.

Stormville limestone series.—By this name Professor White designated in his district all the strata which come in between the Stormville shales and the *Bastard limestone* of the miners; reaching an extreme thickness of 150′. It is *par excellence* the fossiliferous part of No. VI; for, beneath the Bastard limestone only a single fossil is to be found in any of the underlying limestone beds, viz. the little *Leperditia alta.*

The upper half of the series is frequently shaly; and occasionally, near the top, cherty. When the beds are massive they are usually too impure for kiln or furnace. They are only used for flux when mixed with the Bossardville limestone; and in fact there are only two or three quarries in the district on any beds above the *Stromatopora* bed.

The *Stromatopora bed*, which comes about the middle of the series, was originally a reef of coral-like sponge-animal; growing in masses or balls varying in diameter from a few inches to 2′; having a concentric structure, and therefore named *Stromatopora concentrica.* The bed of which they form a large part is usually about 10′ thick, never more than 15′; nearly always quite massive; standing cliff-like from

*Some of the beds next to be described, immediately under the Stormville shale, are often quite sandy but never look like a sandstone, although they are usually massive, and here and there cherty.

the quarry walls; the globular sponges projecting from the surface, because they have resisted the weather better than the rock in which they were imbedded.*

The Stromatopora bed along Montour's ridge is usually too silicious for lime burning or flux; but it is mixed at Grove's quarry with a pure limestone and sent to the Danville furnaces.

Very good limestone beds, largely quarried, underlie the Stromatopora bed along Lime ridge in Columbia and Montour counties; but when followed into Northumberland they seem to become impure and are seldom quarried. They are often quite fossiliferous; especially rich in the scattered fragments of *crinoids* and in *corals*, and (at one place only) the well known chain-coral *Halysites catenulatus*, hitherto supposed to be entirely confined to the Niagara formation.†

Baldy's quarries in Limestone township, Montour county, are on these beds; dip 20° (N. N. W.) G 7, 321. The massive beds of this series make the crest of Limestone ridge

* A similar *Stromatopora* horizon has already in the last chapter been described as appearing in the middle of the Stormville limestone series on the Delaware river; and we will see directly that a reef of the same sort occurs in the same series both at Selinsgrove and at Georgetown on the Susquehanna below Sunbury; and also on the upper Juniata. We have seen that *Stromatopora* beds occur in the Lower Helderberg beds in eastern New York. While the distribution of these sponge reefs over an immense area of the Appalachian sea bottom in the Lower Helderberg age is therefore an undoubted fact we cannot be sure that any particular *Stromatopora* bed in any one locality is continuous and identical with any other *Stromatopora* bed elsewhere. A *Stromatopora* bed shows in its proper place in the north dip at Selinsgrove, but not in the south dip. At other places in middle Pennsylvania *more than one Stromatopora* bed occurs in the same section. In fact these sponges continued to live into the Upper Helderberg age; so that we have *Stromatopora* beds above No. VII as well as below it.

† *Halysites catenulatus* has been seen at only one place in this district (Mauser's quarry, Montour township, Columbia county, see section given above) where a massive limestone bed contains vast quantities of it; its beautiful chain-like tubes covering the rock surfaces. In fact stratum 20′ consists quite as largely of chain-coral as the Stromatopora bed 5′ above it and 12′ thick consists of *Stromatopora concentrica*. *Halysites catenulatus* has hitherto been regarded as perfectly characteristic of the Niagara formation (*under* the Salina formation); therefore its occurrence here in Lower Helderberg formation No. VI (*over* the Salina formation) is a great discovery; and shows that this particular coral survived through several ages sufficient for a deposit of a thousand feet of strata.

in Turbut township, Northumberland county while the Oriskany sandstone makes the southern slope, and the Bossardville limestone its northern slope (G 7, 332).

Bastard and Bossardville limestones.

Bastard limestone (*Peth-stone of New Jersey; Stormville cement bed*).—This is the name in common use at all the quarries in Columbia and Montour counties for a series of light-gray or buff-gray, tough, impure limestone beds overlying the Bossardville quarry beds. The presence of these upper (bastard) beds at the quarries enhances the cost of the work. Where the dip is slight the *bastard* beds have to be broken up and removed so as to uncover the quarry stone. Where the dip is steep deep cuts or tunnels have to be driven through the *bastard* beds to allow of the quarry-beds being worked in a long trench behind and beneath them; in which case the *bastard* beds are left to make a great overhanging ledge. At the Lime Ridge quarries the bastard beds are broken up and carried off for rough building work, bridge piers, etc. The thickness varies from 10′ to 30′. Analyses have been already given (see page —— above); but the magnesia probably often exceeds the percentage giving in the table. *Atrypa reticularis*, *Strophomena rhomboidalis*, *Rhynchonella formosa* and some minute *Beyrichias* (?) are the most common fossils.

Bossardville limestone (*Quarry rock*).—From the color, structure, and general character of these beds there can be no doubt of their identity with the beds quarried along the Delaware river outcrop described in the last chapter. They are the only beds constantly pure enough for lime burning. In Northumberland county no other beds are wrought. Only from these beds can white plaster lime be anywhere procured. Analyses are given in the table (page — above). They often occur in thin flaggy layers, only one or two inches thick. Their color is usually very dark-blue; more frequently bluish black; the color appearing still stronger by contrast with the multitude of thin veins and strings of pure calcite which traverse them; these being cracks in which the dissolved carbonate of lime has been re-precipitated in a crystalline form.

Leperditia alta sometimes occurs in the less pure parting layers, but it is absolutely the only fossil form to be found in the mass ; the average thickness of which is 100′; sometimes a few feet more, or a few feet less ; but the whole of this mass is not good limestone ; near the centre come, in many places, 20′ or 30′ of impure beds.

The outcrop of these most valuable strata is frequently concealed in this district (as in the Delaware river region) by local *débris* from the neighboring hills ; and undoubtedly future quarries will be opened beneath the drift. In Frosty valley, for instance, there are no quarries for 10 miles between Buckhorn and Mahoning creek ; the outcrop being here buried beneath stuff which has filled up an ancient river valley excavated along the northern foot of Montour ridge. The existence of the quarry limestone beds beneath the drift is not to be doubted ; for they are seen going under at Little Fishing creek, just east from Buckhorn, and coming out again at Mahoning creek. If it be objected that the covered drift would be too heavy to strip, the answer is that the depth of the drift must vary greatly from point to point along the outcrop, and can be easily discovered by boring ; so that while in some places the limestone beds will undoubtedly be too deep to quarry, in others they may lie quite near the surface. This is especially true for the three miles east of Danville ; and a line running N. 80° E. will pass close over the uppermost beds for several miles. There undoubtedly exists a continuous concealed outcrop all the way up the river to Berwick.

No. VI quarries in Columbia county.

Mauser's quarry, half a mile east of the Montour-Columbia county line, on the railroad, has had its section already given on page above.

Appleman's quarry is just east of Mauser's. Here the main 8′ bench is exclusively worked to a depth of 30′ for a quarter of a mile along the strike, as the Bastard beds would make it too expensive to reach the upper limestones, the dip being 40° (S.) (G7, 246).

Eck's quarry is about half a mile east of Appleman's. Here the section is (G7.247):—

Eck's quarry section.

Limestone, bluish grey; *quarried*, ...		8′
Stromatopora bed, a mass of corals, many of them beautifully dissected out by the weather, . . .	10′	30′
Stromatopora, *Favosites*, *Zaphrentis*, *Crinoidal fragments*, and a delicately branching *Cladopora*, most numerous; also *Atrypa recticulata*: in a blueish grey limestone, *quarried*, ...	20′	
Slaty limestone (dip 38° to S. 15° E.), ...		5′
Bastard limestone, buff grey, full of minute shells, probably *Beyrichia*, ...		15′

Bossardville quarry limestone beds.

Dark-blue, flaggy, best bench, ...	20′	73
Blue-gray, shaly, flaggy (½ to 1 inch), upper half *full of Leperditia alta*,*	30′	
Blue-black, thicker beds, ...	15′	
Shelly, ...	5′	
Blue-grey, ...	1′	
Shelly, blue-grey, ...	2	
All beneath concealed, ...	?	

Mensch's quarry, a quarter mile east of the school-house, is one of the oldest in Columbia county, having been worked for sixty years.

Mensch's quarry section.

Limestone, blue-gray, full of *crinoidal* fragments, and other forms, ...	10′ to 15′
Shaly grey limestone, a little quarried, . .	6′
Bastard limestone, unusually thick, holding *Atrypa reticularis*, *Strophomena depressa*, *Rhynchonella formosa*, and Beyrichia, ...	30′
Bossardville limestone, principal quarry rock, blue-black, thin layers, veined with calcite, ...	25′

Here the *Bastard* beds, dipping 35° to 40°(S.) overhang the cavations. The top of the *Bossardville* is quarried along the hill slope east and west.

Evans' quarry, east of Mensch's, where the beds emerge from beneath deep drift of coarse reddish sand, and make a solid rock dam across Fishing creek five or six feet high,

* Cover the faces of the layers by thousands.

50′ of the series being exposed in the banks ; the lower beds showing a rude *cleavage* and *columnar* structure (*stylolites*) dipping very steeply (N.) whereas the true bed planes dip only 25° to 30° (S.) Glacial drift covers the outcrop here ; as it does the whole line of outcrop across Bloomsburg township.

Creveling's quarry, at the West Scott township line, is extensive ; the beds dipping 45°+ (S.) (G7, 257).

Creveling's quarry section.

Shaly blue limestone, ...		15′
Magnesian, ochery, impure limestone, ...		7
Shaly dark-blue limestone, ...		13
Stromatopora bed; upper part, dark grey, rough with many fossils, but not a mass of them as elsewhere, . . .		20′
Bastard limestone, buff-grey, ...		15′
Bossardville blue limestone, quarried, . .	25′	50′+
Black blue layers ; also quite pure, ...	25′	
Bottom beds of series covered up, ...	?	

Boone's quarry,* a few rods further west, shows the lower beds which are concealed at Crevelings, thus :—

Bluegrey, hard, limestone, ...			12′
Bastard limestone, ...			12′
Bossardville	blue, ...	25′	95
	dark-dlue, thin bedded, ...	20′	
	blue-grey, thin bedded, . . .	20′	
	dark, blue, thicker beds, ...	30′	
Salina? buff, shaly, impure, magnesian			?

Low Brother's quarry in Centre township, Columbia county, just below Lime Ridge RR. station, has been already given in section (p.— above.) Here the *Stromatopora* bed is undiscernable because there are no weathered outcrops, and the fossils are indistinct on fresh surfaces. The upper layers of Bastard break square, and the lower layers are full of *Beyrichia*. The *Bossardville* is 105′ thick, mostly a very dark laminated rock, making the whitest lime.

* Much stone is shipped from these two quarries to the furnaces at Bloomsburg and Danville ; and large quantities are sold for lime burning, for farm lime, and for building purposes. Further west the high ridge (50′ to 75′) of limestone has several smaller quarries in it, and then sinks beneath the terrace drift ; coming up again at quarries half a mile east of Espey Station.

Wooley's quarry, just east of Low's, opposite Lime Ridge station, Centre township, shows:

Gray, shaly, limestone, with many fragmentary fossils; *Atrypa reticularis;* an Orthis; Cladopora (multipora?); and a fragment of a trilobite, *Dalmanites*, was got from it,	5′
Stromatopora concentrica bed; with coral Favosites and Zaphrentis; and the shells, *Rhynchonella formosa* and *Strophomena rhomboidalis*, ...	10′
Bluegrey limestone beds, ...	25′
Bastard limestone beds, ...	20′
Bossardville (upper) *quarry beds*, ...	40′

At this quarry Lime ridge rises abruptly to 110′ above the drift terrace, the rocks dipping 30′+(S. S. E.), and runs westward unbroken for nearly a mile. Eastward no such ridge exists, being buried under the drift. Hess' quarry is at the west end of the ridge, in 60′ of *Bossardville beds*, under 15′ of *Bastard beds*. West of this, the ridge sinks with its *Bossardville quarry beds;* leaving at the surface, in a bluff, some limestone layers of Salina age, 50′ lower in the series; 20′ of them exposed, quarried by Pohe & Miller, and abandoned.

Lead and *Zinc*. This is the place where a New York mining company once prospected for the ores; found a little and abandoned the ground (G7, 262).

Martz's quarry, on Briar creek a mile west of Miller's, is extensive, in almost black, thin, flaggy layers, streaked with calcite veins, in all about 30′ thick; no fossils (G7, 264). West Briar creek flows in drift filling an old *buried river valley*, under which runs the quarry rocks; how deep should be discovered by systematic boring.

Petty's quarry, a mile northeast of Berwick, east side of Briar creek (abandoned) exhibits light gray, slaty, somewhat impure beds (not slacking freely), dipping 35° (N. N. W.), 25′ exposed, probably near the base of the Bossardville group.

Martz's quarry, just west of Petty's, has been long worked in 40′ of Bossardville dark blue hard beds; over which lie 6′ of bluish slaty beds; over which lie bluish grey beds.

Evans' quarry No. 1, just west of Petty's, is extensive; in *non-fossiliferous* (Bossardville), almost black, flaggy beds, through which run many seams of calcite.

Evans' quarry No. 2 (abandoned), just west of No. 1, was formerly worked in *fossiliferous* (higher) gray beds, rough and sandy, not slacking well. Here can be collected *Strophomena rugosa*, *Atrypa reticularis*, *Stromatopora concentrica* and *other fossils.*

Ecks' quarry (abandoned) at the west township line, is in the slaty, non-fossiliferous, impure lowest Bossardville beds (G7, 272).

No. VI quarries in Montour and Northumberland.

Grove Brothers' quarry, near the Columbia county line, north of the railroad, is drained by a tunnel, a section of which has been given on page —— above. The *Stormville Conglomerate*, and *Stromatopora bed* are well seen. In the black layers of the Stormville shale can be collected a curious branching seaweed (*Buthrotrephis*) with flattened stems from ¼″ to ½″ broad. The *Decker's Ferry sandstone* of the Delaware river in Monroe, absent in eastern Pike, is also absent from this Montour outcrop. The *Bossardville beds* are here also pure, flaggy, black and totally destitute of fossils. Under this pure group lie the *Salina upper* impure, magnesian, buff gray and pale green limestones ; and under these the great *Bloomsburg red shale.*

Appleman's (*Christy's*) *quarry*, half a mile west of the Grove tunnel, is in a ridge 85′ high above the Marcellus outcrop valley south of it, and 40′ above the Salina valley north of it (next the mountain.) The *Stromatopora reef* makes a bold cliff edge, over shaly limestone, under which comes *another Stromatopora reef*, with multitudes of corals. A third and lower *coralline* bed lies on the *Bastard group ;* thus (G7, 300) :

Appleman's quarry section.

Shaly limestone, somewhat sandy, ...	3′
Stromatopora bed ; a solid reef of *S. concentrica.* Some of the masses apparently silicified, ...	15′
Shaly limestone, somewhat sandy, ...	5′
Coral beds ; great numbers of corals (*Favosites, Zaphrentis, Cladopora, Conophyllum*) with many *Stromatopora balls,*	15′
Gray limestone, quite sandy, ...	5′

Crinoid bed; vast quantities of crinoidal fragments; with *Cladopora* and other fossils,	15
Bastard limestone (overhanging the quarry),	20′
Bossardville dark blue limestone; black and quite pure;* dipping 35° (S. S. E), and quarried in a long trench; no fossils; many calcite veins radiating through the dark mass; makes beautiful white lime,	40′
Bossardville blue gray, slaty, impure, limestone, visible for	10′

West of this the ridge disappears; but the quarry rock could be found by digging down 50′ or 60′ beneath local drift; for at York's quarry the *Stromatopora bed* and 15′ of underlying beds have been quarried; the Bastard and Bossardville remaining underground to beyond the Mahoning township line, and in fact to Danville. Here at the river bridge the *Stormville shales* and 25′ or 30′ of layers under them are all that can be seen (G.7, 306.) In Rush township, south of the river, the quarry beds are concealed. In Point township, Northumberland county, the long outcrop of No. VI is mostly covered by the terrace drift (G7, 340). Sink holes however betray its course and the existence of extensive caves in it underground. One such, north of the school house (Watson's) 2¼ miles east of the West Branch, is a perfect funnel in shape, 50′ across and 35′ deep.

Rohrabaugh's quarry, 1¼ miles east of the West Branch, is extensive, and ships flux to the Susquehanna Valley iron furnaces. *Snyder's quærry*, ½ mile farther east, in the black beds, is small.

Rohrabaugh's quarry section.

	Bastard limestone, dull gray, impure,	15′
Bossardville limestone.	Gray shale,	25′
	Blue-gray, massive,	12′
	Blue-black,	25′
	Gray, laminated, shaly,	30′

On the West Branch is an old quarry (long ago abandoned) on the Stromatopora beds, dipping 45° (S. S. E.); and on the Union county bank of the river are the extensive quarries of the Lewisburg Iron furnace.

*None of the beds above the Bastard are pure; all of them are somewhat silicious.

No. VI quarries along the northern outcrop.

An old buried valley runs along the north foot of Montour's ridge, covering up No. VI, except here and there where it makes a short low ridge and gives a chance to quarry it. One such rises near the eastern township line of Liberty, Montour county. Here on McWilliam's land the *Bossardville beds* were once worked. Another is on Moody's land near the western township line.

Troxell's quarry is 2 miles from the West Branch in Northumberland county, where 10′ of the *Bastard beds* are seen; and under them the *Bossardville beds*:—dark gray, 10′; dark blue, 3′; blackish blue, 30′; blue shaly thin layers, 5′ = total, 58′; making a continuous ridge. They have been quarried also a little east of Troxell's quarry. The *Stromatopora bed* shows at Mrs. Yount's further east (½ mile) a perfect mass of *S. concentrica* and *corals* at an old abandoned quarry on the Stormville beds (G7, 334).

No. VI quarries in Limestone Ridge.

The Milton anticlinal brings up No. VI one mile east of Washingtonville, Derry township, Montour county, where *Mrs. Patterson's* quarry exposes 16′ of bluish flaggy limestone, dipping 6°+(N.).—*Seidel's* large quarry at the Fair Grounds shows 15′ dark blue limestone (no fossils), over 5′ of dark brown sandy *building stone* beds (all else in this neighborhood being concealed by drift) each 4″ to 6″ thick, breaking square along two systems of joints (G7, 318).

Limestone ridge runs west, along the limestone township line, high and sharp; the Oriskany making a steep scarp along its southern brow; No. VI making its north slope. The *Stormville shales*, blackish, sandy, 75′ to 100′, make the vale near Baldy's.

At *Baldy's quarries* the *Bossardville upper beds*, and some beds above them are extensively worked, dipping 20° (N.N.W.). *Mauser's quarry*, further west, shows the section given on page——above.

Caldwell's large quarry, on a run cutting through the ridge, works the *Bossardville lower beds* for farm lime (G7, 320).

Mosteller's, Funks' and other quarries along the high Limestone ridge (between Turbut and Chillisquaque townships of Northumberland county) are on the steep north slope, in the *Bossardville beds*, which are here thinner and less pure (G7, 332).

Chapter LXIX.

No. VI on the Susquehanna at Selinsgrove.

Sinking (with a south dip) 2½ miles north of the junction of the two branches of the Susquehanna at Northumberland, beneath the great Catawissa-Sunbury synclinal of Formations VIII and IX, formation No. VI is brought to the surface again by an anticlinal, the axis of which crosses the river above Selinsgrove, three miles below Sunbury. This anticlinal axis sinks eastward rapidly; so that the north and south dipping outcrops of No. VII and VI converge eastward and join about two miles east of the river. The arch is a fine one as shown in Fig. 92, pl. 27, G7; the north and south dips being nearly equal, about 40° on the sides and horizontal on the crest. The arch is about 3000′ wide from where No. VII descends to water level *northward* to where it descends to water level *southward.* Half this space in the center of the arch is occupied by No. V. The horizontal breadth of the outcrop of No. VI both on the north and on the south of the arch is about 1000′.

Two miles further down the river the axis of a second and lower anticlinal arch brings up only the top beds of the formation. This arch also sinks rapidly eastward. These two arches, rising westward, make together the great compound anticlinal of Shade mountain which traverses Snyder and Juniata counties 40 miles, and dies down westward at Lewistown.

The two following sections show formation No. VI on the two sides of the higher or northern arch, and with a total thickness of nearly 500′.

The first section was obtained on the north side of the *Selinsgrove arch* in passing southward from the little stream which empties into the Susquehanna river at the mouth of Shamokin creek (along the Northern Central

Railroad) to the center of the anticlinal arch near the 135th mile post (Fig. 93, p. 342, G7).

Selinsgrove north dipping section.

1. *Hamilton shales*, olive brown, with a layer of iron carbonate ½′ thick, both at top and base, ...	
2. Brown, olive, sandy shales, breaking in long splinter-like pieces, ...	150
3. Concealed, dip N. 10°–15° W. 30°, (doubtful), ...	400′
4. *Marcellus black slates* and shales, ...	135
5. Concealed, ...	60′
6. Dark slaty shale, ...	5′
7. Concealed, ...	50′
8. *Selinsgrove limestone*, bluish gray, once quarried and burnt by Beckon and Lantz, ...	20′
9. Gray, impure limestones interstratified with much shale, ...	30′
10. *Selinsgrove* bluish and gray sandy *shales*, uppermost 30′ somewhat limy, ...	150′
11. Concealed, ...	20′
12. *Oriskany sandstone No. VII*, dirty yellow cherty fossilferous, limy and sandy beds, ...	57′

Stormville shales, 110′.

13. Limy, cherty beds interstratified with much gray shale,	55′
14. Shaly beds, limy, ...	5′
15. Buffish and blue impure limy shales, ...	10′
16. Dark shale with abundant remains of a *fucoid* resembling *Buthotrephis*, ...	10
17. Limy shales, ...	10′
18. Concealed, ...	20′

Stormville limestone, 205′.

19. Impure limestone, ...	5′
20. Concealed, ...	90
21. Limestone, impure, somewhat massive, ...	25′
22. Concealed, ...	10
23. Impure limestone, ...	2′
24. Shaly limestone and concealed, ...	7′
25. *Tentaculite limestone*, bluishgray, containing *Tentaculites irregularis* and fragments of fossil shells, . . .	1′
26. Limy shales and shaly limestone, ...	45′
27. *Stromatopora bed*, ...	10
28. Bluish-gray limestone, massive, ...	10′
29. *Cement beds* (?), gray limestone, weathering into small nodular masses, ...	75′

Bossardville group, 133'.

30.	Dark blue and gray limestone good,	25'
31.	Limestone, impure, bluish-gray,	40'
32.	Limy shales and shaly limestone,	45'
33.	Blue limestone, good,	11'
34.	Shales,	2'
35.	Bluish-black limestone, very poor,	10'
36.	*Salina*, buff and pale green shales and shaly limestone to center of Selinsgrove arch, ... visible	115'

Summary.

VIII.	*Hamilton* and *Marcellus*, No. 1–7, inclusive,		805'
	Selinsgrove limestone, Nos. 8–9, inclusive,		50'
	Selinsgrove shales, Nos. 10–11, inclusive,		170'
VII.	*Oriskany* sandstone,		57'
VI.	Shale,	110'	523'
	Limestone,	413'	
V.	*Salina*,		115'
	Total,		1720'

The Oriskany is a mass of impure, limy, cherty beds in layers 2″ to 6″ thick, often containing *Spirifera arrecta*, *S. arenosa*, *S. macropleura*, and other fossils.

It is possible that the concealed interval of 20' in No. 11 should also be placed in the Oriskany, since its surface is covered with small blocks of *Oriskany sandstone*. Those blocks of *Oriskany sandstone* which have been subjected to atmospheric influences for a long time acquire a character totally different from the rock in its unweathered condition; for having lost their lime and iron through a leaching process they become bleached to a grayish white rock, rather porous, and from which the sand grains stand out quite as prominently as if from a typical sandstone. They also break in weathering into small cubical blocks none of which are more than 6″ on a side.

The *Stormville shale* apparently includes only beds 13 to 18, and has therefore a thickness of 110', or 15' less than on the south side of the arch. It contains some beds of impure, cherty limestone very much like that in the *Oriskany* above, and in the dark shale, bed 16, occurs a species of *fucoid* with narrow ribbon-like fronds, branching quite irregularly, being exactly like one occurring in the *Stormville shale* in blocks taken from the tunnel of the Grove Bros. at the eastern line of Montour county.

The Stormville limestone series seems to begin with bed 19, a bed of bluish gray impure limestone of which only 5′ are visible. Allowing this to be the top the whole group sums up a thickness of (413′–343′) 70′ more than the same limestones on the south side of the Selinsgrove arch. The only chance for mistake in measurement that would lessen this discrepancy is to be found in the concealed interval No. 20; but as the horizontal distance through this is 180, and the dip on both sides greater (32°–35°) than 30°, the assumed dip, it would seem that the vertical interval represented cannot be much less than 90′ as given.

The only *Tenaculites* observed in the *Stormville limestone* anywhere within the district occur in the little bed of of bluish-gray limestone No. 25. They occur quite sparingly in this, and seem to be identical with *Tentaculities irregularis.*

The Stromatopora bed, No. 27, is most probably the equivalent of the great *coral reef horizon* in the *Stormville limestone* through Columbia and Montour counties, since it seems to be especially rich in *Stromatopora.* In this, and the 10′ of massive limestone immediately below, were seen *Strophomena rugosa*, *Atrypa reticularis*, *Spirifera sp?* *Favosites helderbergiæ*, *Zaphrentes sp?* and a large *Orthoceras*, probably *O. multicameratum*, besides many fragments of *Crinoids*, especially abundant in No. 28.

The Stormville cement bed of Monroe, *i. e.* the *Bastard limestone* of the Columbia and Montour quarries, seems to be represented by the lower part of No. 29. At any rate it is quite impure, and some of it looks *magnesian.*

The Bossardville limestone (Nos. 30–35) appears to be 133′ thick on this north side of the arch; on the south side (Nos. 15–21) only 118′. Beds 30, 33, 35 of this northern section and beds 15, 19, 21 of the southern section correspond; and all have been extensively *quarried* and shipped for lime burning for flux and other purposes along the Northern Central railroad.

Selinsgrove south dipping section.

VII.	1. *Oriskany*, cherty, sandy beds, ... visible	20	
Stormville shales.	2. Limy shales, gray and concealed with some chert,	50′	125
	3. Impure, gray limestone, and shale, . . .	25′	
	4. Dark shales, and black slate, with some thin, impure, blackish limestones, and bluish-gray shales, ...	50	
	5. Limestone, massive, hard, somewhat sandy, and fossiliferous, ...	10	
	6. Blue, shaly limestone, ...	5	
	7. Limestone, bluish-gray, massive, fossiliferous, containing several layers of chert in upper half, ...	10′	
	8. Blue limestone, interstratified with shales,	8′	98′
	9. Impure, bluish-gray limestone, with some magnesian layers, ...	75′	
	10. Shaly, bluish-gray limestone, ...	15′	
	11. Massive, bluish-gray limestone with many specimens of *Strophomena rugosa* (*rhomboidalis ?*), near the top, ...	30	
	*Stromatopora bed, not seen in this section.**		
Bastard limestone.	12. Hard, bluish-gray, curly, impure limestone, weathering rough and into nodules in terraced layers, ...	50′	72′
	13. Shaly limestone, ...	10′	
	14. Blue limestone, and shales, ...	12′	
Bossardville limestone.	15. Massive, dark-blue and gray limestone, extensively quarried for lime, quite pure, ...	20′	118
	16. Gray, banded, impure limestones, exhibiting *columar structure*, ...	30′	
	17. Shales and concealed, ...	10′	
	18. Shaly limestone, and limy shales, ...	35	
	19. Dark-blue limestone, pure, ...	8	
	20. Limy shales, ...	3′	
	21. Limestone, bluish-black, very pure, extensively quarried, together with No. 19, base of *Lower Helderberg*, ...	12′	
V.	22. Buff, shaly and pale-green impure limestones and limy shales (*Upper Salina*) to level of R.R. at crest of *Selinsgrove axis* 150 yards south from the 135th mile-post, ...	90′	
	23. Concealed to level of Susquehanna river, . .	25′	

Summary.

VII.	*Oriskany*, . .	visible 20′	
VI.	*Shale*, Nos. 2–4 inclusive, ...	125′	468′
	Limestone (Nos. 5–21), ...	343′	
V.	*Salina*, Nos. 22-23, ...	visible 115′	
	Total, ...	603′	

* The fossil balls stand out boldly on weathered surfaces ; but are detected with some difficulty on freshly blasted or broken surfaces.

The Stromatopora bed was not noted in this section on the *south side* of the arch, having very probably beeu overlooked in some of the beds that are little weathered ; for on freshly broken or quarried surfaces the *Stromatopora* are with difficulty distinguished from other portions of the rock.

Lead and Zinc ores in No. VI. (*G7, 100*).

The Bossardville limestone outcrop (north dip) at Selinsgrove junction contains these ores in small quantities. They were first brought to notice nearly 50 years ago, and some ore was shipped in barrels on the Pennsylvania canal; but no further steps were taken to mine them until in 1882, when Mr. Dougherty of Shamokin undertook systematic prospecting on the horizontal crest of Selinsgrove anticlinal, near the 135th mile post of the Northern Central railroad. The ore occurs in a bed about 10′ above the base of the Bossardville group, in strings and pots, mixed with a large amount of muddy rubbish resembling deposits made by a stream of turbid water flowing among rocks. The course of the deposit appears to run with the strike of the beds, which is here nearly east and west. Several tons of ore lay on the dump when visited in 1882 ; and samples selected at random were sent to the laboratory of the survey at Harrisburg to be analyzed by Mr. McCreath. He found in them :—metallic lead 24.191 ; metallic zinc 31.954; metallic copper 1,389 ; the lead and zinc existing as sulphides ; the copper as a carbonate. If the quantity of ore were great a mine of importance could be established here ; but the experience of prospectors for lead and zinc ores in No. VI in various counties of Pennsylvania has been always so disappointing; and the circumstances under which these ores in No. VI have been found to lie both here and elsewhere make it almost certain that the quantity obtainable by ordinary mining operations would practically amount to nothing. (G7,100).*

* Small quantities of lead and zinc ore have been found in the Bossardville limestone in Columbia county about halfway between Lime Ridge and Espy, near the Scott-Centre township line, where a trial tunnel was once driven and abandoned ; although masses of lead ore (Galena) more than a

No. VI. on the Georgetown and Urban arches.

Formation No. VI, dipping south at Selinsgrove, descends to a probable depth of 15,000′ to the bottom of the great middle anthracite coal basin at Port Trevorton (6 miles down the river), and then rises more rapidly to the surface on the anticlinal which crosses the river at Georgetown (6 miles below Port Trevorton); then descends to a depth of 13,500′ beneath the Wiconisco anthracite basin.

On the Georgetown axis the whole formation appears above water level ; comes to a point about a mile west of the river and descends beneath the surface. East of the river it extends 5 miles before it disappears underground.

The Urban axis runs parallel to the other, and one mile north of it, bringing up No. VI in the same manner, but beginning to do so 3 miles east of the river, and carrying it eastward 5 miles to and beyond Urban post office, where No. VI comes to a point, descends and is seen no more. On the north side of this Urban axis, near the Jordan township line, at Emerich & Lebo's quarries, 2½ miles east from Georgetown, the second section of the two sections given below was obtained ; the beds dipping northward about 55°.

Two miles below Georgetown the great anticlinal of Tuscarora mountain ought to pass the river but dies out before reaching it. This arch with its two long outcrops of No. VI, passing the Juniata below Millerstown and below Perrysville, will be described in another chapter.

The Armstrong valley anticlinal which crosses the river 2 miles above Halifax only brings to the surface the upper beds of No. VIII ; so No. VI remains beneath water level.

Just above Georgetown in quarries north of the Lutheran church we see buffish impure limestone 50′; and under this bluish black limestone 25′; dipping (N. 10 W.) 40°.

A short distance south from Georgetown, the Upper Salina are just brought out above river level. A mile below

foot in diameter were taken out. Similar small quantities of Galena obtained from the Bossardville limestone, or the top beds of the Salina immediately under it, along Warrior's ridge west of Huntingdon, have been already noticed in the chapter on Formation No. V.

Georgetown No. VI is well exposed in the cuts of the Northern Central railroad as follows :—

Georgetown south dipping section. (*Fig. 28, G7. 84*).

VII.	*Oriskany sansdtone No. VII*, ...	50
VI.	*Stormville shales*, and dark gray with some cherty beds near center, ...	100′
	Stormville limestone, gray, shaly, fossiliferous, . . .	50′
	Limestone, massive, bluish, gray, fossiliferous,	10′
	Impure, buffish, gray, fossilferous, ...	25′
	Bastard limestone, bluish gray, massive, fossilferous, .	50′
	Bossardville limestone.	
	(a) Dark blue pure limestone, ...	20
	(b) Bluish gray impure beds, ...	10′
	(c) Blue limestone, good, ...	15′
	(d) Shaly, bluish gray limestone, impure, ...	40′
	(e) Bluish black limestone, quite pure, . . .	30′
V.	*Salina beds*, drab and buff shales limestones and lime shales to center of arch, one mile below Georgetown, .	100′

The Oriskany here is massive, and less cherty than in the northern outcrops; holds *Sp. arenosa*, and *Rensselœria ovalis* in considerable abundance, with other badly preserved species. The No. VI limestone beds are generally impure; only 65′ of the whole 250′ being pure enough to burn ; the 30′ at the bottom is the best and is extensively quarried.

The Bossardville limestone, quarried by Emerick & Lebo, dipping (north) 50°–60°, exhibits the following sections at the quarry and along the road north from it :

Georgetown north dipping section (*G7, 370*).

VII.	*Oriskany sandstone*, yellowish, some chert, visible, .	40′
VI.	*Stormville shales*, ashen-gray to dark brown, some limy, others cherty, *Spirifera macropleura* and *Strophomena depressa* quite abundant, ...	75′
3.	Massive sandy limestone, full of chert, ...	7′
4.	Shaly limestone and concealed, ...	25′
5.	Massive, impure limestone, bluish gray, cherty at top for 5′,	20′
6.	Concealed, ...	40′
7.	*Stromatopora bed*, a bluish-gray limestone filled with fossil corals of which *Stromatopora concentrica* is most abundant, ...	10′
8.	Bluish-gray limestone, impure, having the "Bastard bed," as the lower half, ...	45′
9.	*Bluish black limestone*, quite pure, ...	25
10.	Impure shaly limestone to bottom of exposure, ...	20′

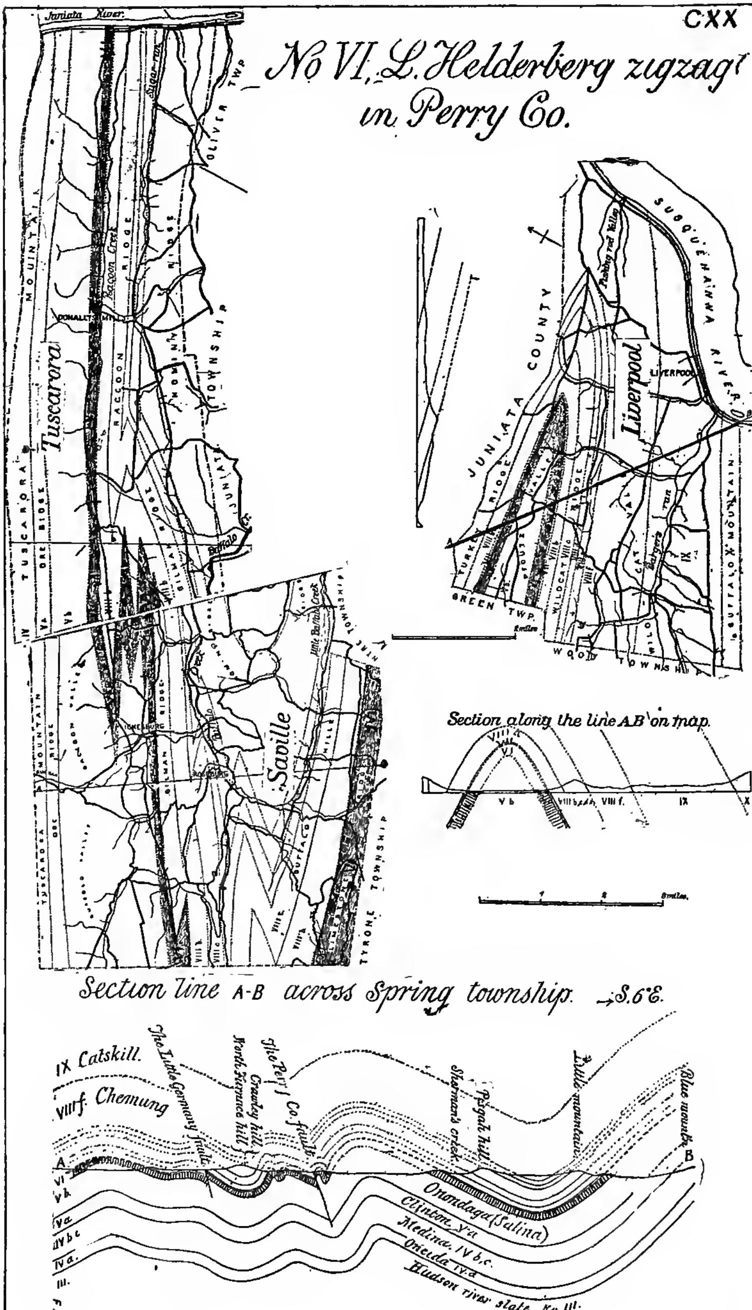
The Oriskany here makes a bold ridge, and shows its usual fossil *Spirifera arenosa.*

The Stormville shale group holds near its middle several thin layers of chert; only a few of the shale layers are dark, the most being ashen-gray.

The *Stromatopora bed* is a perfect mass of *Stromatopora Favosites*, and other *corals*, but seems to lie lower than is usual in this district, i. e. 92′ below the top of the limestone series (instead of 50′ to 60′); but this may be explained by a thickening up of the occasional little limestone layers which occur every where in the Stormville shale series. The three groups 75′, 7′, 25′, if they represent the Stormville shale series, would give its usual thickness, 107′.

The Bossardville limestone upper beds are here as usual blackish and make good lime.

As for the fossils of this district, *Atrypa reticularis*, *Strophomena depressa*, *Strophomena rhomboidalis* (*var-rugosa*), *Rhynchonella formosa*, and *Rhynchonella ventricosa* and a *Zaphrentis* were found to extend from the Bastard limestone upward ; *Spirifera macropleura* was only found in the Stormville shales ; *Tentaculites gyracanthus* (a single specimen) and *Orthoceras cameratum* were found in the upper half of the Stormville lime shales; *Halysites catenulatus*, *Cladopora multipora* (?) and *Favosites helderbergiæ* were found in the lower half; *Stromatopora concentrica* was found in the middle ; *Beyrichia* of two or three species and *Leperditia alta* were collected from all parts of the series ; *Ambocoelio biconvexa*, Claypole, extends from the Bastard limestone up to the base of the Oriskany. Many more were in fragments too poor to indentify. Others would be found on a more thorough search.


CXX
No VI, L. Helderberg zigzag in Perry Co.
Section along the line AB on map.
Section line A-B across Spring township. →S.6°E.
IX Catskill.
VIII f. Chemung
The Little Germany fault
North Furnace hill
Crawley hill
The Perry Co fault
Sherman's creek
Pisgah hill
Little mountain
Blue mountain
Onondaga (Salina)
Clinton V a
Medina IV b,c.
Oneida IV a
Hudson river slate No. III.
Tuscarora
Saville
Liverpool
Juniata River
Juniata County
Susquehanna River
Buffalo Creek
Raccoon Ridge
Green Twp.
Wood Township
Tyrone Township
Oliver Twp

Chapter LXX.

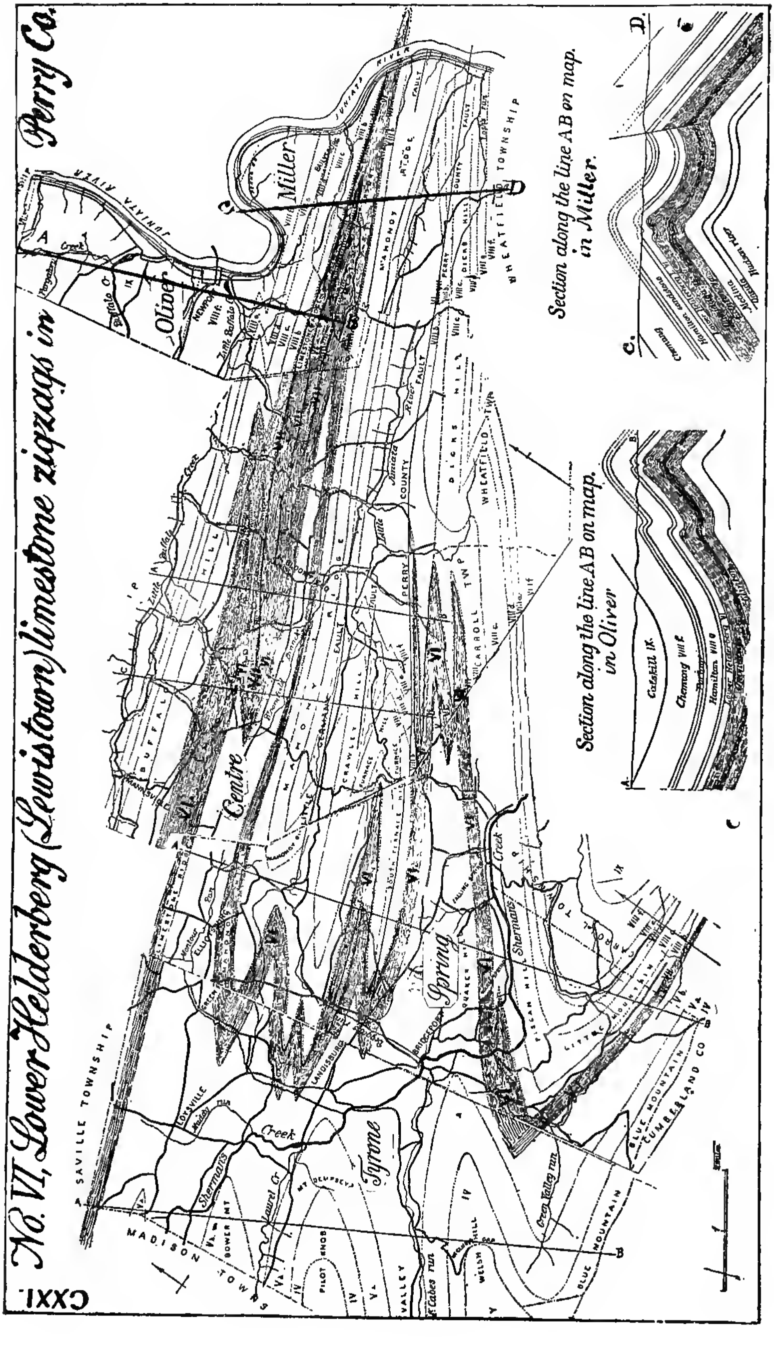
No. VI in Perry County on the Lower Juniata.

The formation has here been well studied by Professor Claypole with the express purpose of defining its subdivisions and locating the horizons of its characteristic fossils. Its top is well defined by the remarkable but variable *Oriskany sandstone No. VII*, standing in cliffs, or cut into picturesque pulpit-rocks. The base of the formation on the contrary is ill-defined; the *Bossardville group* graduating downward into the *Salina shales* and marls; so that it is impossible to draw any sharp plane of division between the two formations VI and V; and certain passage beds must remain debatable ground, all the more because they are nearly barren of fossils in Perry county.*

No. VI. Generalized section.

No. VII.	*Oriskany* sandstone,				25′±
No. VI.	*Flint shales*	White,	10′		350′±
		Yellow,	80′		
	Black cherty limestone,		8′		
	Clarks Mill (Stormville) lime-shales.	Tentaculite bed,		150′	
		Polyzoan bed,			
		Beyrichia granulata bed,			
		Leptaena bed,			
		Stromatopora bed,			
		Sphærocystites bed,			
		Rhynchonella bed,			
		Murchisonia bed.			
		Beyrichia notata bed,			
	Lewistown (Bossardville) limestone, massive,		100′		
No. V.	*Salina*,				——

*An independent set of names was adopted by Professor Claypole to designate the subdivisions of No. VI; his survey being contemporaneous with that of Professor White. But the principal reason for adopting local geographical names peculiar to Perry county was the great importance of certain outcrops in view of the abundance and well-defined succession of their animal forms.



CXXI. No. VI, Lower Helderberg (Lewistown) limestone zigzags in Perry Co.

Comparing this with the Lower Helderberg section in eastern New York it looks as if the *Upper Pentamerus limestone* was absent; as if the *Encrinital limestone* was represented by the flint shales; as if the *Delthyrus shaly limestone* and *Lower Pentamerus limestone* together were represented by the Clark's mill lime-shales; and the *Tentaculite division of the Water Lime*, by the massive Lewistown limestone.* It is impossible to correlate the Mohawk and Juniata sections in detail, as every geologist and palæontologist would expect to be the case beforehand, their distance apart being 200 miles; but when the two ranges of fossil horizons are compared there is both agreement between them and disagreement.

Lewistown limetone. Fossils are very scarce in Perry county; the only one that can be looked for at most exposures with a reasonable expectation of success is the *Leperditi aalta;* and, as we have seen (page 949 above), this is the one solitary fossil form in the Bossardville group on the North Branch. This little shell has not been seen in Perry county in any of the beds *above* the Lewistown limestone; but, on the other hand, it ranges *downward* through the Salina formation to a great depth; and therefore cannot be considered characteristic of the Lewistown limestone: in eastern New York however the *Water lime* is characterized by not only this *L. alta*, but also by several other species; among which is *Tentaculites ornatus* (*Gyracanthus irregularis*). But this *Tentaculite* occurs in Perry county at the top of the Clark's Mill limeshales, i. e. 150′ above the Lewistown limestone; and in company with *Spirifera vanuxemi* (*Orthis plicata*).

The *Clarke's Mill lime-shales group* corresponds very well, in a general way, with the New York *Lower Pentamerus limestone* and *Delthyrus shaly limestone;* but differs in detail. In both groups we have the same limy character, the same profusion of fossils, and to a great extent the same prevailing species, but a somewhat different arrangement of horizons.

*The name *Lewistown limestone* was established by the earlier surveys of 1874-5, in Mifflin county; and corresponds to White's *Bossardville limestone.*

A partial list of fossils common to the Clark's Mill lime-shales and the New York Delthyrus and Lower Pentamerus limestone groups is as follows :–*Discina discus*, *Strophomena rugosa*, *Rensselaeria mutabilis*, *Rhynchonella nucleolata*, *Rhynchonella formosa*, *Meristella laevis*, *Meristella bella*, *Megambonia aviculoides*, *Murchisonia minuta*.*

The total absence of any species of *Pentamerus*, and any species of *Platyceras* in the above list is noteworthy. But it must be borne in mind that only one (in fact the only good) exposure of the group, namely that at Clark's Mill, has been examined with sufficient minuteness to certify their actual absence from the whole district.

In the *Flint Shale group* fossils are few, except that its topmost white flint beds are often crowded with casts, among which *Spirifera macropleura* and *Strophomena rugosa* are especially abundant.† The bottom layers of the group (immediately overlying the black cherty limestones) abound in silicified *crinoidal joints*, and may therefore (with or without the cherty beds) be the equivalent of the Encrinital limestone of New York ; but there is nothing in the New York section at all resembling this large flint deposit in Perry county. This is hardly to be wondered at, for there is no sign of it in the tunnel section of the Mapleton sand-works on the Juniata river in Huntingdon county where soft red and yellow shales occupy the position of the flint-beds of Perry county (F2, 61).

Description of the subdivisons of No. VI.

It has been said already that the top of No. VI is well defined, although its actual contact with the base of No. VII has nowhere been seen. The concealed interval amounts nowhere to more than a few feet; but there is no indication of a gradual change of white-flint shales upward into the overlying sandstone which appears in full force a few feet above them.

*The list might be much extended by further study and collection.

† We have seen that the beds immediately underlying No. VII in the Montour district are similarly rich.

The *White-Flint shales* are so named because they hold two massive white-flint rock-layers, which are exposed in a few places near the mouth of Cocolamus creek in northwest Juniata township and also at Half Falls mountain. These two beds, each one foot thick, and separated from each other by two feet of shale, cumber the fields along the line of their outcrop with chunks of rock often measuring a cubic foot, which must be carted off before the land can be cultivated.*

The *white flint* is very fossiliferous; the *yellow flint* is apparently barren of fossils. The *white-flint fossils* may be examined at leisure in the hugh stone-piles which skirt the fields along its outcrop; but the brittle texture of the stone, and its habit of fracturing at right angles, make it almost impossible to secure the fossils in conveniently small hand specimens.

The *Yellow-flint shale.*—Thin shets or layers of yellow flint characterize the upper part of this sub-division; breaking up readily under the action of frost; and becoming bleached by the air and light; so that fields along the outcrop present a perfectly white surface, and are sometimes so thickly covered with flint stones that one would suppose their cultivation impossible; yet the soil is by no means unproductive; on the contrary, it ranks high as a soil, being known all over the country as *flint gravel soil.* The belt of outcrop covered by this soil (occupying the space between the underlying limestone outcrop and the overlying Oriskany sandstone outcrop) is well marked; but no good exposures of the shale rock can be got. The lower beds are very flinty, with black chert in lenticular sheets, often covered with a limestone crust.†

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* In this respect the white *flint* differs from the *yellow flint*, next to be described, which breaks into small pieces, and therefore does not at all interfere with plowing.

† *The origin of chert* has been much in dispute between those who have ascribed to it an organic origin, the microscopic, silicious needles (spicules) secreted by various kinds of sponges to support their soft bodies by a sort of universal skeleton, and those who prefer to consider Chert a direct precipitation from sea water heavily charged with dissolved silica. Recently the subject has been handled by Prof. Hull, the director of the Irish Geological Survey, and Mr. Hardman, the chemist, adopting the latter theory, and by Dr. Hinde,

The Clark's Mill lime-shales.—These form a group (100′ to 150′ thick) of thin-bedded limestone layers and lime-shales. The limestone layers are not massive, but furnish equally good lime with the underlying more massive *Lewis-*

of England, whose microscopic examination of the Chert beds in Ireland, Wales and England have resulted in a pretty certain demonstration of the correctness of the opposite organic theory. The joint paper on the subject by Messrs. Hull and Hardman may be found in the Scientific Transactions of the Royal Dublin Society, Vol. I, New series, 1878, pages 71 to 94, with a plate. Dr. Hinde's statement is published in the report of a paper read before the British Association at Manchester, 1886. Mr. Hull reached the conclusion that the Irish Chert beds and also the Chert nodules in the sub-carboniferous limestone of Ireland is essentially a pseudomorphic rock, consisting of gelatinous silica replacing limestone of organic origin, chiefly foraminiferal, crinoidal, and coralline; the replacement having taken place while the limestone was plastic, admitting the percolation of silicious water, before the overlying shales were deposited upon it; the sea being largely charged with silica in solution; and the chemical process of transmutation accelerated by the warmth of the water owing to the shallowness of the sea. Mr. Hardman gave the results of numerous analyses of the Chert, showing that it consisted principally of anhydrous silica reaching up to 95.5 per cent., with a varying admixture of carbonate of lime, iron, and a few other minerals. (*Geological Magazine*, London, October, 1887, page 435.) Soon afterwards Prof. Renard, of Brussels, published a paper in the Bulletin of the Royal Academy of Belgium, Vol. XLVI, pages 471 to 498, with a plate, in which he offers the same explanation for the origin of the Chert beds (phthanites) of Belgium as formed by the silification of the organic and inorganic calcareous elements of the carboniferous limestone, while the sediments were to a certain extent plastic. Mr. Renard adds that it is impossible to explain the formation of the Chert masses by the accumulation of the silicious skeletons of sponges, and that there is nothing to prove that the silica of the Chert was derived from the decomposition either of sponge-spicules or the solid parts of microscopic diatoms.

Prof. Hult was influenced chiefly, to all appearance, by what he supposed to be the scarcity of sponge-spicules in the Chert. Dr. Hinde, on the contrary, bases his opposite opinion entirely on what he asserts to be so great a multitude of sponge-spicules in the Chert as virtually to make up its whole mass. Of course this is a question of observation; and one or other of the two observers must have been deceived by the appearance of the objects in the field of the microscope. In 1881, Prof. Sollas published a statement in the Annals and Magazine of Natural History, Vol. VII, page 141, that some of the microscopic sections described and figured in Prof. Hull's paper show that sponge-spicules make up the larger part of the Chert. In 1880, Mr. H. J. Carter, F. R. S., published in the same Annals, Vol. VI, page 213, his microscopic examination of beds of clay discovered by Messrs. Wright and Stewart of Belfast, apparently resulting from decayed Chert, in some parts nearly entirely composed of sponge-spicules. Dr. Hinde, after making himself familiar with the microscopic aspects of the sponge-spicules which are much better preserved in the great Welsh Chert beds than they are in the Irish Chert. re-examined Mr. Hull's microscopic slides and found *town (Bossardville) limestone beds* of the quarries. Fossils abound in all the outcrops of this group although only one complete exposure exists, viz: at Clark's mill in Centre township.

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them to be completely charged with sponge-spicules which had been mistaken by Mr. Hull for the stems of corals. He says that when a chance section of the ossicle of a crinoid does occur in Prof. Hull's slides, the distinction between it and the sponge-spicules is readily apparent, for not only is the Crinoid fragment much larger, but it also exhibits the minute cribriform structure peculiar to echinodermal organisms which is so well known, and serves to mark them off from sponge formations. Nearly all the sections made by Dr. Hinde were prepared from the prevalent dark Chert. This, when viewed by reflected light under the microscope, showed a diffused, cloudy, bluish-white net-work on a dark ground; by transmitted light, the bluish portion becomes translucent, and when the section is very thin, transparent; and is resolved into microscopic sponge-spicules, confusedly intermingled together, whose individual outlines can be traced with varying degrees of clearness. In transverse section the spicules appear as well-defined circles, often with a central spot indicating the axial canal; in longitudinal section the larger spicules show two parallel lines with a clear space between them, not so distinctly seen as the transverse circles In most of the sections sponge-spicules are the only organisms visible. In some there is a slight admixture of specimens of *Fenestella* and other Polyzoa, the cells of which are now filled with either chalcedony or quartz. Rarely also are seen fragments of minute Brachiopod or Entomostracan shells; and one or two microscopic ossicles of Crinoids; but no Foraminifers were seen by Dr. Hinde. The dark material in the Chert is mostly disposed in wavy bands following the plane of bedding; some of it consisting of very minute opaque crystals, but most of it having a cloudy appearance; apparently partly carbonaceous and partly ferruginous.

Sections of the light brown Chert show in addition to sponge-spicules numerous well-defined microscopic cubic and rhombic crystals, either entirely or partially transparent or opaque; .02 to .05 mm. in diameter (smaller crystals in the dark Chert are in fewer numbers); the spicules have a brownish, cloudy aspect in transmitted light; with extremely jagged outlines showing that they have suffered and been greatly diminished from their original size by some dissolving agent. It is undoubtedly this dissolved or decayed condition of the sponge-spicules as seen under the microscope that has deceived Prof. Hull. The Chert has suffered from this dissolving agency in another way which deserves special consideration.

The dark Chert and the brown Chert differ in color because the latter is undergoing a process of bleaching, analogous to the slow formation of the well known *patina* of the cretaceous Chert. This patina is an outside skin of whitish aspect penetrating to a greater or less depth the black mass within, and showing the depth to which weathering has gone. The antiquity of arrow-heads, hammer-heads, etc. of Chert, found by archæologists, is proven by the patina, or whitish skin, which has been given to them in the course of time; and the forgeries or fraudulent imitations of them, so well known to archæologists, are detected by the absence of this natural patina, or by the unnatural look of an artificial patina which the forgers endeavor

The Lewistown (Bossardville) limestone.—This group of massive laminated dark limestone beds furnish most of the quicklime for the district; the brown stone slacking readily in the air; no indication of hydraulic cement

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to give to them by the application of acids. It is evident that the imperfect condition of the sponge-spicules in the Chert is due to their passing through various stages of dissolution, many of them having become faint or nearly obliterated, Those in the patina or crust ought to show the same result. In fact, in most cases the crust of the Chert appears under the microscope to consist only of minute silicious grains; but under favorable conditions of preservation it is seen to be composed of innumerable minute red-like sponge-spicules, intercrossing, and as it were felted together irregularly in the plane of the bedding of the rock. Layers of porous silicious rock sometimes take the place of solid Chert layers, and were evidently at one time solid Chert layers, but have been subjected to the dissolving action and lost their organic forms; and yet the microscope finds in them also matted masses of minute sponge-spicules.

It is remarkable certainly that not a single entire sponge has as yet been discovered in any of the great Chert beds of the Yorkdale series (Sub-carboniferous) in Yorkshire and North Wales, although these unique Chert beds reach an estimated thickness of between 100′ and 150′, wholly built up by the dropped skeleton needles of successive generations of colonies of sponges living on through a whole geological age; existing continuously and almost exclusively in the same area for long poriods. It is only under such circumstances, when the mass of life was exclusively that of the sponge animal which secreted in its body no limestone but only silica, that a layer or bed or continuous series of beds of Chert could have originated. In those parts of the sea bottom where the sponges had not the exclusive possession of the ground, but lived in company with Crinoids and Polyzoa which secreted for themselves lime skeletons, the deposit could not be a layer of Chert but a layer of limestone, distributed through which were the cherty nodules produced by the sponge-spicules. Under such circumstances also the interspaces of the corals were filled up by silica, resulting from the partial solution of the sponge-spicules. Such layers we now call cherty limestone. Dr. Hinde remarks also that under certain conditions, when the lime-secreting animals greatly exceeded the sponges, the sponge remains are frequently more or less dissolved and replaced by calcite (crystallized carbonate of lime); and this may be observed by the aid of a pocket lens in some of the dark limestones of the Calp series near Dublin, showing numerous sponge-spicules, which, when treated with acid, are dissolved away equally with the limestone matrix, leaving only a few small hollow fragments in the residue; but the sponge-spicules in this limestone are larger than those in the Chert bed, and appear to belong mostly to the Tetractinellid sponges.

The Irish dark Chert is described as compact, breaking with a concoidal or splintery fracture, too hard to be scratched with a knife, and usually unaffected by acid; fractured surfaces usually dull, sometimes with the faint lustre of the Lydian Stone; often banded; the beds sometimes traversed by minute thread-like fissures filled with quartz; upper and under surfaces of the beds weathered to a light gray or whitish silicious crust (sometimes nearly an inch thick) of a porous granular material, harsh to the feel, adhecharacter observable. The thickness of the group, judging from numerous but imperfect exposures, does not exceed 100′. The more massive beds (2′ to 4′ thick) are in the middle of the group; above and below them the beds are thinner with partings of shale increasingly numerous ascending and descending from the middle sub-division. The limestone is hard, dark, often bituminous, and traversed by veins of calc spar. The weathered surfaces of the rock show that it is laminated, that is, composed of alternate darker and lighter very thin leaves or layers, which have no disposition to separate under the action of the air. The hard solid thick bedded mass near New Bloomfield measures 60′ to 70′, appearing at the surface on the slope of the ridge at many places. The dark color of the fresh broken

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sive to the tongue, strikingly contrasting with the compact black central Chert in the bed. Occasionally the entire mass of the Chert bed is converted into this porous rock, looking like pumice stone and relatively of much lighter weight. Where Brachiopod shells, Crinoid stems, etc. were in it, nothing but their casts remains.

The extraordinary thickness of the British Chert beds may be imagined from these facts:—In Yorkshire are beds of Chert 18′ thick without a break; in North Wales there is a continuous series of them without the intervention of limestone, 350′ thick. The Irish Chert series is much more interrupted. Near Sligo Chert beds and nodular masses occur at frequent intervals throughout the Sub-carboniferous limestone series for 800′. Dr. Hinde estimates the proportion of Chert to limestone at from one-tenth to one-fifth. Near Enniskillen, Prof. Hull estimates 150′ of Chert bands in a total of 400′ of the upper limestone series. In the south of Ireland, the upper portion of this upper limestone series is said to consist of almost entirely of a mass of Chert from 30′ to 50′ thick. Apart from the conclusive demonstration of the sponge origin of these immense layers of Chert; it would strain the imagination to suppose that such quantities of silica could be thrown down upon any part of the sea bottom by any chemical process whatever, even supposing we had a method of explaining in what way the sea water could be charged with such an amount of gelatinous silica, inasmuch as any chemical process would be necessarily a comparatively rapid one; whereas if the beds of Chert were produced by successive generations of sponges living in massive banks, time becomes a prime factor in the problem and any amount of it can be used in the explanation. The question of the gelatinous character of the silica becomes important. Prof. Hull concluded from his microscopic observations that the Chert was in a gelatinous or colloid condition, and therefore precipitated; but Mr. Hardman was puzzled by the fact, made evident by his analysis, that in all cases the silica was present in the insoluble form; and Dr. Hinde, examining the Irish sections between crossed Nichols, substantiated the accuracy of Mr. Hardman's analysis by showing that the Chert presented the optical characters of chalcedony and quartz.

rock becomes lighter on the outcrop surfaces. Its bituminous odor when struck with a hammer makes the quarrymen call it *sulphury.* When burnt the stone makes a strong white, hot or *fat* lime much valued for builders' mortar, wherever magnesian limestones yielding a cool or *lean* lime cannot be got. It acts on land more quickly and safely than the magnesian lime In Centre township most of the farmers quarry and burn it for themselves.*

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* *Lime and its use upon land.*—The only minerals of commercial value yet discovered in this county are limestone and iron ore. The former is almost confined to the Limestone ridge and other outcrops of the Lewistown limestone. Immense quantities of stone have been taken from different parts of Limestone ridge largely as a flux when the furnaces were in blast, and since then for liming land, for which it is well suited. All the limestone in the county is low in magnesia, much almost a pure carbonate of lime. It yields consequently a "hot" or "fat" lime, less convenient for the purposes of the builder than the "cool" "lean" lime derived from the dolomitic limestones of other places. It slakes soft, and crumbles down to powder, showing that it possesses little or no hydraulic properties and therefore is low in alumina. No hydraulic limestone or cement beds are worked in this county, and, so far as I have learned, none have ever been found there. Attempts have been made to burn some of the lime shales at the base of the black shale for this purpose, but without success.

The vexed question of the advantages of liming land has not been solved in Perry county. Both sides have strong advocates. Men who have persistently limed the black shaly land for many years maintain that it has much improved under the treatment. But the general disuse of lime of late in the county is an argument on the other side. Probably both views would be considerably modified if all the concomitant circumstances were taken into the account. The experience of farmers in this region supplies no new argument against the position now taken by most agricultural chemists that lime is a stimulant and not an enricher of the soil. If the soil contains nutritive material the lime can render that material more readily available; and in this way it is advantageous to land where stores of plant-food are locked up. But if the land contains no such store the addition of lime can never bring forth any. Limestone soils are as much improved by the addition of lime as are the shaly soils, whether black or red, because the lime applied is in a very different chemical condition from that which naturally exists there. The unburnt lime of the soil is quite inert as a decomposer of plant-food; but when burnt and rendered caustic its decomposing energy is developed. In the stone the lime is combined with carbonic acid which completely masks the active property on which its value as a stimulant to the soil depends. But in the kiln this carbonic acid is driven off, the stone loses about half its weight, and its power of decomposing organic matter is developed.

For the same reason a limestone soil, as it is called, if it really contains any lime, contains it in the same form, the carbonate. Hence the lime if naturally present in the soll is of no value as a stimulant; it is inert; and

No. VI. Limestone boulder slabs.

The farmers prefer to quarry new stone instead of using that which often lies thickly over the surface of the ground, brought up by the plow in the form of thin flat slabs, bevelled at the edges and ringing under the hammer. The

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the addition of quick or caustic lime has exactly the same effect both in nature and amount as on any other land. The secret of the value of lime in agriculture lies in the chemical fact already alluded to, that quick or caustic lime has the power of decomposing animal and vegetable matter. Hence lime *in this caustic state* speedily destroys organic material and reduces it to a condition in which it is available for plant food. But it is obvious that the amount of plant-food thus produced will depend on the amount of organic matter existing naturally in every soil, and unless this store is in some way replenished it must before long become exhausted.

The liming of land therefore year after year without the application of *manure* of some kind must end in the reduction of the natural store of plant-food below that which will yield a paying crop, as is the case with not a little of the poorer sort of land in Perry county at the present time. Some the farmers are in the condition of men who possess an annuity, but overdraw it every year, thus reducing the principal, dollar by dollar, until it falls too low to afford them a living.

An intelligent farmer aided by a knowledge of the chemical principle above laid down, will see that he can only secure an advantage from lime by placing in the ground a supply of organic material which the lime will convert into plant-food. This supply may be obtained by manuring it; by allowing to lie fallow, when the weeds which spring up and die will add their remains to the soil; or, by growing some green crop upon it, such as clover, the tops and especially the roots of which contribute largely to its stock of organic material (A crop of red clover is said to yield about 8 tons of roots). This is attacked by the lime when added, and is quickly decomposed, whereas naturally the process would require a much longer time. Hence liming the soil does not really add anything to its fertility, but only anticipates the future and brings back the farmer in one or two years what would otherwise spread over more. The farmer should also bear in mind the fact that quicklime when exposed to the air rapidly absorbs from it carbonic acid, and returns to its former condition of carbonate of lime, when it is of little or no use to the land.

Lime should be applied *fresh;* for, a heap of burnt lime left in the open air rapidly recarbonates itself and loses most of its value. If it cannot be spread at once it should be well covered with earth to prevent the absorption of carbonic acid. A few drops of muriatic acid (or spirits of salt) if added to carbonate of lime will cause strong effervescence or bubbling, owing to the escape of the gas, whereas if added to quicklime little or no effervescence will ensue. In this way the good or bad condition of a stack of slaked lime may readily be determined.

The use of lime does not, however, altogether end here. In some parts of Perry county, especially those which lie upon the red sandstones of the Catskill group, the soil and sub-soil contain a considerable quantity of *potash* in the form of silicate of potash. When lime is added to such soil abundance of these stones gives the surface of the fields an appearance of sterility, which is however deceptive, because the soil is in reality fertile. But these weathered limestones are seldom picked off for burning, because they burn in the kiln with difficulty. In some places they are crowded with the little *Leperditia alta.*

Folded structure and zigzag outcrops.

The great breadth of the outcrop of No. VI in Centre township of Perry county has been produced by the wonderfully close folding of the formation from side pressure (See plates XV, figs. 1, 2, F2, 174; pl. XVI, 176 and the map pl. XII, 168).* The formation, which is only 300′ or 400′ thick, is thrown into vertical folds, repeating the quarry beds 6 or 8 times; the folds lying tightly pressed against each other. But they are sometimes separated by a fold of Oriskany sandstone which has been pinched into

as this, it changes the silicate of potash into silicate of lime, and sets free the potash, which is carbonated. *Carbonate of potash* is one of the most valuable materials for growing plants. Such soils contain within themselves a reserve of this locked up plant-food which ages cannot exhaust. It must not however be inferred from the above-stated fact that this red sandstone soil does not need manure. Plants cannot live or grow upon potash alone, though potash is one of their most important constitutents. They require many other chemical elements, which must be supplied in the shape of manure. Again, when new boggy land is broken up, the soil is often *sour* from the presence of *humic acid* produced by the decay of vegetable matter. In some cases it is too sour to allow the growth of anything but the natural swamp grasses and sedges. Lime is alkaline or anti-acid in property, and therefore its application in considerable quantity is productive of immediate benefit in diminishing the acidity and rendering the soil suitable for the growth of more profitable crops.

As to the details of the application of lime, the time, manner, quantity, etc. experience is the best guide, and the farmer can determine these points for himself. But a knowledge of the chemical principles above given will guide an intelligent man in the use of this valuable but much abused stimulant, which, like many others when used alone and unwisely, develops a short-lived energy, but ends in greater exhaustion.

From what has been said it is evident that the addition to the land of finely powdered limestone is totally useless as a substitute for quickliming. It may have a good mechanical effect on some soils, like that produced by sand, coal ashes, etc. but cannot stimulate their fertility. (Claypole, F2 pp. 103 to 104.)

* Reproduced on a reduced scale on plates CXX, CXXI, on pages 966 and 968 above.

the crease. In some cases the north dipping beds are not only vertical but overturned to a steep south dip; in other cases the south dips have been thrown over to steep north dips. The ridges of Oriskany therefore represent lines of synclinal between the folds and unite in sharp zigzags east and west.

Perry county fault.

The earth movement from the south which produced the folds in the quarry beds of Centre township, acting on the entire column of formations, has in several instances broke the whole mass along lines (E. N. E. and W. S. W.) many miles in length. The principal fault (described in F2, pl. VI, page 82) has been traced 18 miles. It throws up the country in the south wall of the fault more than 4000′; bringing to the surface the quarry limestone No. VI against the Chemung strata of No. VIII. The plane of the fault seems to have a southward dip of about 70°; the quarry limestones standing vertical against the edges of nearly horizontal Chemung shales. It is just here, at the fault, and where it is at its maximum, that we see the quarry limestones repeatedly and closely folded as above described.*

The Little Germany fault, running parallel to and a mile north of the long Perry county fault, has only been traced five miles; but it produces the same complication of strata and noteworthy changes in the landscape. It can be detected first toward its horizon on the hill west of Little Germany, where it produces a fork in both the Oriskany No. VII and the limestones of No. VI. These have been quarried and burnt here at a distance of only 100′ south

*This place is about six miles east of New Bloomfield at the north foot of Dick's hill, where there are quarries of the Bossardville limestone of No. VI. Here the throw of the fault is greater than anywhere along its line to the west; and so far as the measurements can be made. 4650′ of rock has been shifted, which is equivalent to a vertical throw of 6510′. This, the most interesting of all the faults in our state (because it affects formations which have been locally studied with great care especially for their fossil contents, and because it is so plainly marked by the appearance at the surface of the Bossardville quarry beds) might be discussed in connection with any of the other formations which it cuts and throws.

from (and apparently *overlying*) the black Marcellus shales of No. VIII. The limestones dipping south are overlaid by south dipping Oriskany, and this again by south dipping Marcellus. Further east the fault at the present surface of the ground affects only Hamilton rocks, and its greatest throw measures say 1150′.

A small third intermediate fault only a mile and a half long throws Hamilton rocks about 300′, and therefore only affects our Bossardville limestone at 1000′ underground.

No. VI quarries in Perry Co.

Quarries in No. VI are most numerous in Liverpool township at the northeast corner of Perry county on the Susquehanna. Here the great Tuscarora mountain anticlinal which crosses the Juniata a mile above Millerstown and the Susquehanna three miles above Liverpool is sinking so rapidly eastward that the south dipping outcrop of No. VI in Wild Cat ridge meets the north dipping outcrop in Turkey ridge, and points down underground on the axis three miles before it reaches the river, at a point two miles northwest of Liverpool. From this point back along the outcrop to the Juniata at Millerstown many quarries have been opened and a great quantity of lime burned. The long narrow pointed valley enclosed between the two ridges of Oriskany No. VII is called Pfoutz' valley, and this is now the great store house for limestone for all the country around. The crest of each ridge is made by the outcrop of No. VII; the inside slope by the flint group; the foot slope by the quarry limestones, well exposed, lying high, and easily worked. Of late years however, the lime kilns at Georgetown, on the east side of the Susquehanna, have competed with the Liverpool kilns, the lime being reputed of better color.

In these quarries the upper rubbly beds are usually exposed underneath the Clark's mill fossiliferous shales, and over the more solid limestones; and they yield very few fossils except the ubiquitous *Leperditia alta*. The quarry beds dip steeply from the center line of the valley northward and southward; but lie nearly flat on the axis at the east head of the valley, where however the limestone lies low and cannot be so easily quarried.

The Flint shale division at the top of No. VI has a magnificient outcrop; making a ridge; and in many places whitening the land with a covering of blocks precluding cultivation; but fortunately this strip is never wide; it runs round the edge of the valley outside of the limestone and inside of the sandstone of No. VII (F2, 242).

In Madison township the zigzags of the great northern basin of Perry county spread No. VI as a broad belt of quarry ground which narrows westward through Jackson township to a point at New Germantown. This synclinal fold is well seen at Hall's quarries north of Blaine in Jackson township, where 50′ of limestone is exposed. From these quarries most of the lime used in the west end of the county is obtained. The synclinal at Blaine makes a high knoll or knob, and gradually sinking westward makes quarrying more and more difficult. Rhinesmith's quarry however is near the west township line half a mile north of the turnpike, and near by is Kerns quarry (F2, 234).

In Madison township No. VI is thrown into numerous low regular waves, exposing the same outcrops over and over again at least eight times, greatly increasing the quantity of fertile soil. The blue limestone beds are exposed in many places, as at Adair's quarry west of Centre, where 25′ of them are seen dipping 25° (N. N. W.); the lowest beds the thickest; the beds above growing gradually thinner and thinner upward and capped by the Clark's Mill fossiliferous shales. These shales are seldom opened for kiln use on account of the nearness of the more solid quarry beds beneath them. Near Bixler's mills on Sherman's creek a quarry shows all the layers from the *Meristella* beds up to the *Tentaculite* and the Flint beds. Here the usual fossils may be collected, but the exposure is not large. A small quarry on the roadside near C. Shull's house shows the shales dipping 35° (N. N. W.) with the following section (F2, 260):

Shaly limestone layers, holding *Discina discus* and a small *Favosite*,	3′ 0′′
Crinoidal beds,	0′ 3′′
Trematopora bed,	1′ 0′′
Shaly beds with *Meristella levis*, *M. bella*, and *Tentaculites gyracanthus*,	12′ 0′′
Crinoidal bed,	0′ 2′′
Shaly beds with a few *Rhynchonella formosa*,	1′ 0′′

CHAPTER LXXI.

No. VI in Union, Snyder, Mifflin, Juniata, Huntingdon, Bedford and Fulton counties.

In Union county along the North Branch Susquehanna river the series is from 250′ to 300′ thick and may be conveniently divided into—

1. *An upper limestone-shale series*, fossiliferous containing the *Stromatopora bed* near the center and with some good limestone near the base,	100′–150′.
2. *A middle bastard limestone series*, carrying tough, impure limestone beds, very hard and weathering with dificulty; magnesian and never burned,	22′–75′.
3. *A lower massive limestone series*, known east of the river as the "*Bossardville limestone*" and containing most of the good quarry beds; dark blue, non-fossiliferous; with impure bands, 20′–30′ thick at center.	100′.

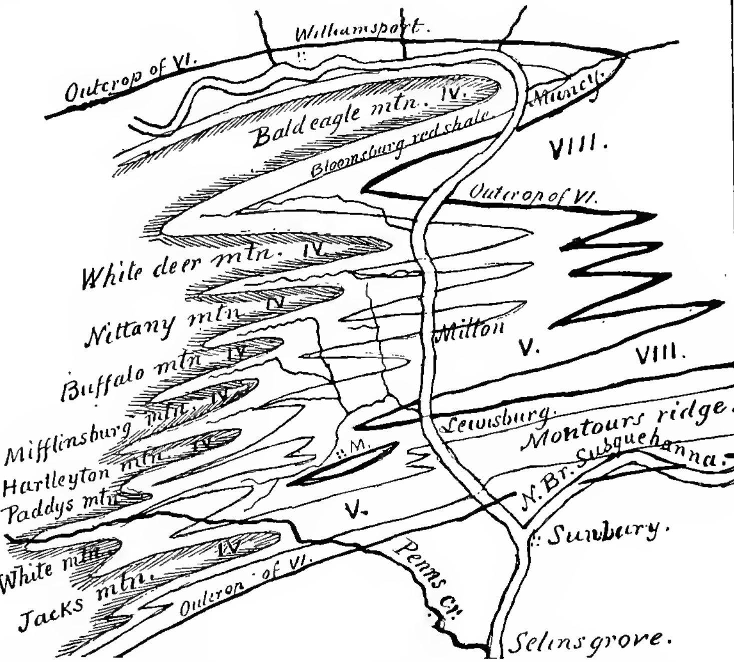
The total thickness of the group averages about 250′ as against 350′ in Huntingdon and 250′ in Perry. It must be remembered in comparing these sections that the "Bossardville limestone" group of the Susquehanna corresponds to No. 5 of the Perry county section and to No. 2 of the Huntingdon county section, the lower division of the latter, 170′ thick, consisting of impure limestone, and in this report considered a part of the next lower group—the *Upper Salina Vc.*

The practical point brought out by this comparison is the fact that the *Lower Helderburg* (*Lewistown*) *formation* in this central district furnishes a series of limestone beds, non-fossiliferous and massive, and about 100′ thick, which contains nearly all of the pure stone of the series, probably averaging 50 per cent. of the entire group thickness, and that the good burning beds are to be sought in this series all along through the Juniata district.*

*The outcrop of VI is shown on Mr. d'Invilliers map of Union and Snyder, in Report F3, 1891, by a deep blue line. Page plate CXXV B shows the zigzags in Union and Snyder counties.

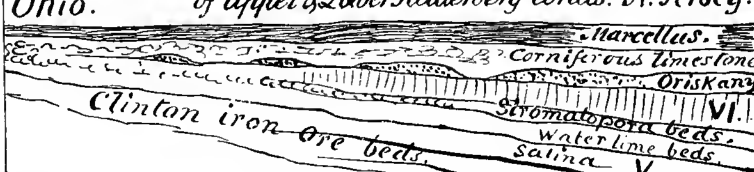
CXXV B.

No. VI. Sketch of zigzag outcrops in Snyder & Union.



Rough sketch copy of J. Hall's specimen.

Diagram section to show connection of Upper & Lower Helderberg corals.



In *Union county* the rocks of formation VI outcrop through Gregg township, where the beds are thin, and are nowhere opened over 50′ in thickness.

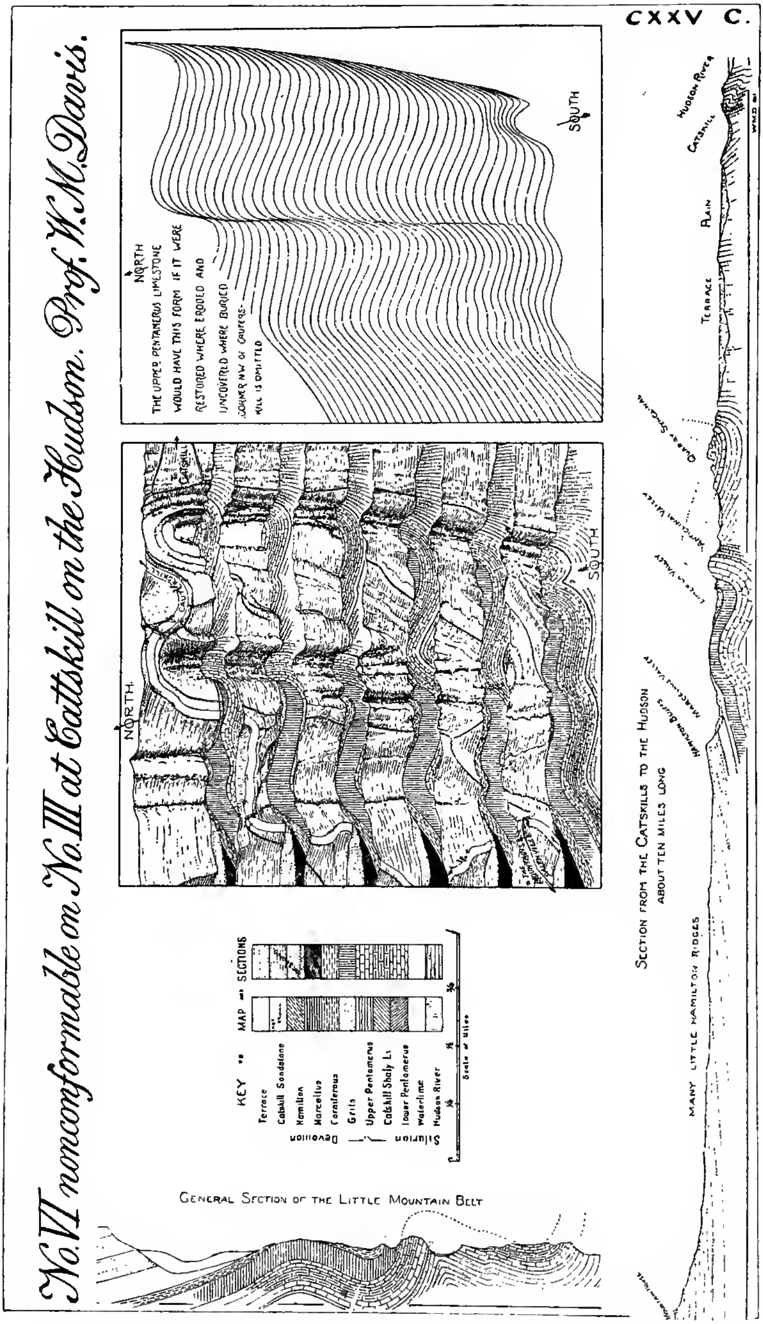
The Lower Helderberg limestones are next seen in the Buffalo Valley synclinal at Lewisburg, making the boat-shaped "*Limestone ridge*," in which several quarries have been opened. Here and along the Mifflinburg limestone ridge the lower massive "*Bossardville*" beds of the group have been opened, without exhibiting any complete section. This division, however with its usual shale partings, is fully 80′ thick and yields an excellent quality of limestone. The upper lime shales are about 110′ thick, and are very fossiliferous, but nowhere quarried.

In Union county the *Winfield quarries*, in the south-east corner, belonging to the Union Furnace Company, exhibit perhaps the best section of the lower Bossardville beds, as they have been more extensively quarried here than elsewhere both for furnace flux and the general market.

The series can be conveniently divided into two divisions. *an upper* (immediately under the shaly beds) 50′–55′ thick and furnishing some good beds; *and a lower*, 48′ thick, holding several massive beds, and yielding both fine grade paper-lime and furnace flux. A bed, 6′ thick, of shelly porous rock, very hard and lean, divides the two groups; the whole forming a series practically 100′ thick.

In *Snyder county* a double outcrop of limestone flanks the Northumberland synclinal, following the line of the Oriskany sandstone already described, and often replacing that rock as the crest of the ridge.

The *Winfield beds* are opened on the north side of the basin in many places as far west as New Berlin; but not as completely as on the river. There is another group of quarries in Kline's ridge, along the same belt as Troxelville; but they are small and show no better sequence of beds. Almost every mile of the south belt from Selinsgrove to Middleburg, Adamsburg and McClure, shows one or more quarries, and while the sections exposed in them



No. VI nonconformable on No. III at Cattskill on the Hudson. Prof. W. M. Davis.

are not very extensive, they all substantiate the general persistency and good quality of the lower division of No. VI as a series of beds of varying thicknesses aggregating close upon 100′.

The *Lower Helderberg series* is perhaps best exposed opposite Selinsgrove on the N. C. RR. on both sides of the Selinsgrove or Shade mountain anticlinal, where they are much thicker apparently than farther north, showing 343′ thick on the north side of the axis, and 413′ thick on the south side, of which about 125′ represents the massive *Bossardville beds.*

On the south side of the Shade mountain anticlinal these same measures may be traced uninterruptedly from below Selinsgrove on the Susquehanna west past Freeburg and Freemont to within 3 miles of the county line, where they form a narrow synclinal basin and high ridge and return to within a mile of Freemont. Here they lap over the Slenderdale axis, and retreat westward again to the Cocalamus creek at Richfield.

Quarries of considerable size are opened in them west of Middle creek and west of Freemont; but only a portion of the massive division, 30′–60′ thick, has been developed in them, and the lime burning industry languishes for lack of railroad communications. A limited amount of No. VI is also exposed in the southeast corner of the county, near McKee's Half Falls, on the crest of the Georgetown axis; but there are no quarries there to show the character of the measures.

In *Mifflin county*, the Lower Helderberg measures are very well developed, showing a somewhat amplified section near the central portion of the belt between Lewistown and McVeytown. It enters the county in a double line of ridges (capped with Oriskany sandstone No. VII) on each side of the slate valley of Decatur township.

The northern belt runs pretty straight through Decatur to Derry township where it makes a synclinal and returns eastward about a mile in an anticlinal ridge with north and south dips of 85° and 50°. Here it turns back again westward to the next synclinal at Logan on the Kishacoquillas, west of which point it extends in an unbroken synclinal of No. VI (in places deepening to receive No. VII and a little of No. VIII) to within 4 miles of the Juniata. East of Logan the basin splits and widens to receive No. VII and No. VIII, folding over again in another anticlinal, entering into Decatur township before returning again westward to the grist mill on the pike north of Lewistown.

The *southern belt* enters the county from McClure and makes a prominent ridge facing the Sunbury and Lewistown railroad all the way to Lewistown, from whence it passes west to the Juniata Sand Works, Strode's Mill and McVeytown. Here the belt and ridge bend southwest and make several small anticlinal and synclinal rolls north of Vineyard station, crossing the river and passing into Huntingdon county about 1½ miles west of Newton Hamilton.

The eastern end of the county is rather sparingly developed; that is to say the quarries are all comparatively small and the section of No. VI limited. Perhaps the best exposure is at the Maitland gap, where the upper division shows about 20′ of shaly and somewhat siliceous limestone, and a lower, more massive division of good limestone 70′ thick.

In *Mifflin county* along the Kishicoquillas creek the character of the Lower Helderberg limestone is well seen. The *upper division* here consists largely of flaggy argillaceous limestone, somewhat quarried for building purposes, but not yielding a good burning-lime; it is about 140′ thick. The Lewistown limestone is about 185′ thick here, showing several massive beds of blue limestone. largely quarried for lime and furnace flux; but the good portion of the deposit does not comprise more than 60′ at the top of the division.

The Logan Iron Company furnace fluxing beds form the middle division of No. VI, which is subdivided thus:

1. *An upper argillaceous and fossiliferous member*, 10′.
2. *A middle good, pure, fluxing limestone-bed*, 50′–60′.
3. *A lower highly silicious member*, not used, 20′.

The company get all their furnace stone from the middle beds 50′–60′ thick, here opened just at the arch of the synclinal. The total combined thickness of the Lewistown shale and limestone in the vicinity of Lewistown, as measured instrumentally for Report F, p. 49 (Logan section), is 140+185=325′; and 300′ may be taken as a fair average for the group in the three synclinals which occur between Lewistown and Ferguson valley. The group holds about the same thickness at McVeytown, although measured sections in Report F show the upper shaly limestone to be 215′ thick, and the lower massive portion about 100′, 50′ being good stone in beds of varying thickness from 1′ to 8′.

On the Juniata below Mt. Union nearly 100′ of stone are exposed in the quarry of the Lucy Furnace Co. about ½ mile from the bridge, the central portion of which, 40′ thick, is a good blue furnace stone.*

In Juniata county the Lower Helderberg limestone formation is somewhat thin. Entering the county on the east at Richfield, its course to the Juniata is practically that of the Flintstone Ridge No. VII, already described, sometimes rising to form the crest of the ridge where the Oriskany sandstone becomes shaly or is absent. A number of quarries have been opened between Richfield and McAllisterville, and south of the latter village: none of great size or importance, but all showing a good stone of uniform general excellence. None of these quarries show over 50′ of stone exposure, and the beds making up this mass are never very thick, 1 to 4′, except in some few instances which are mentioned in the Township Geology. West of East Salem in the north leg of the synclinal an additional series of quarry openings show about the same thing, but not so well exposed.

The outcrop of No. VI, after nearly reaching the river in the synclinal, turns back eastward to East Salem, folds over the Academia anticlinal in a double wrinkle, and

* For the character and thickness of No. VI in Mifflin county see the sections by Ashburner & Billin in plates 81, 82, 83, 84, 85, 86, 87, on pages 640, 642, 644, etc., of Vol. I.

finally turns westward again as the north leg of the main Tuscarora synclinal to Port Royal. Along the basin there are in places as high as 60′ of No. VI exposed; but the individual beds are never over 3′ or 4′ thick, and the good burning portion of the series will not aggregate over 40′ in thickness.

West of the Juniata the outcrop of No. VI on the north side of the Tuscarora synclinal shows but a single line passing through McCoysville and back of Peru Mills to Huntingdon county.

The best exposures are at McCoysville and Peru Mills, at both of which places the limestone beds have been quarried. At McCoysville No. VI shows about 150′ thick, including the upper shaly members, the massive pure limestone at the bottom occurring in a series of thin beds about 40′ thick. At Peru Mills the exposure measures about 50′, with but few large beds.

The south outcrop of limestone in Juniata county forming the south slope of the Tuscarora synclinal, extends from the base of Turkey ridge in front of the Tuscarora mountain gap in Delaware township through Thompsontown to Mexico on the Juniata. There are few good exposures here. At the Hamilton quarries all the good lime is quarried from 60′ of measures, none of the individual beds being more than 3′ thick.

About the same thickness is exposed in Benner's quarry, 1½ miles further west, and on the river below Mexico, where however the upper shaly limestones increase the section by 80′. West of the river the limestone belt makes nearly a straight line past Pleasant View to Bealetown, where it makes a synclinal loop, and at Allen's quarry shows about 60′ thick, dipping N. 30° W. 35°. The stone is evenly bedded and has a sub-crystalline structure, greyish-blue in color, and rather silicious at the base. The upper portion is fossiliferous, the good limestone being about 40′ thick.

West from here to Huntingdon county the Tuscarora creek partially cuts out the section of No. VI, which has evidently decreased in thickness, so that a complete section would scarcely show more than 150′–200′ of measures.*

In *Huntingdon county*, (Rep. T[3], p. 123), Prof. White divides No. VI as follows:

1. *An upper division*, consisting of impure and shaly limestone and containing a 25′ massive layer with *Stromatopora fossils*, ... 133′.

2. *A middle division*, dark blue massive limestone, not fossiliferous, and containing mostly good limestone beds, 90′.

3. *A lower division of shaly*, impure limestone, . . 170′.

The total thickness of the formation is thus about 300′, varying from that up to 400′ in other parts of the county. All the good beds most quarried are confined to the middle division, 90′–100′ thick.

At Powell's quarries, near Cove station, at the Bedford county line, the succession of these strata can be easily studied.

UPPER DIVISION, 133′

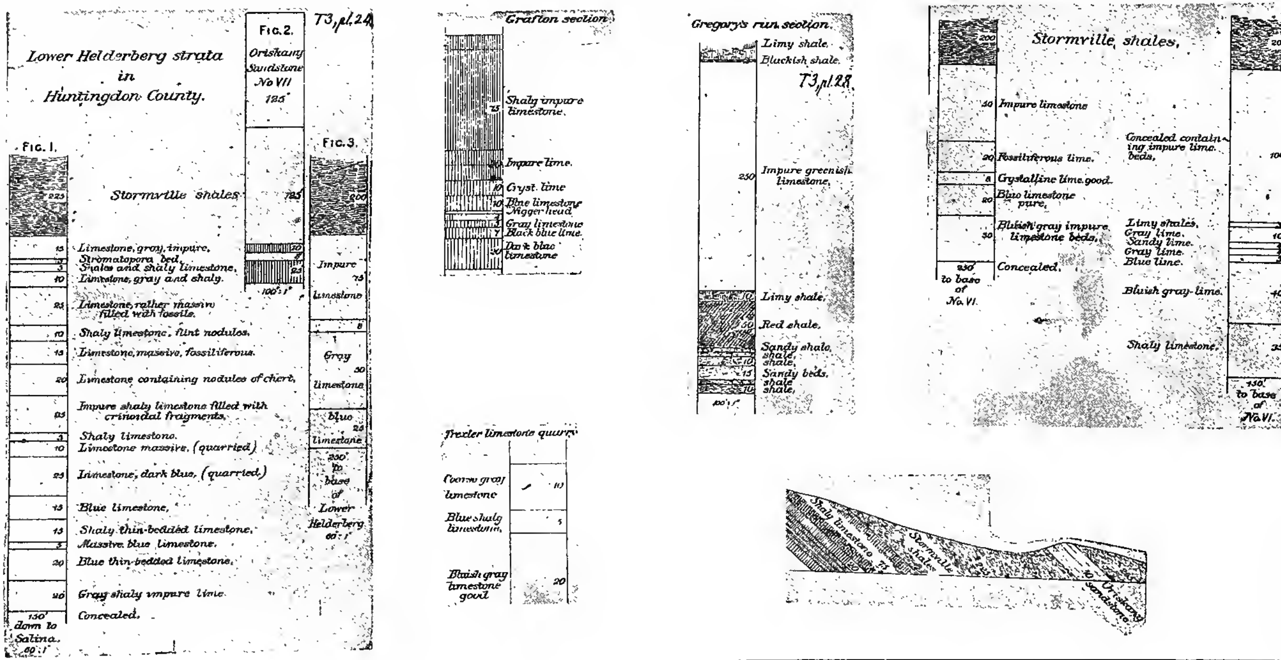
Limestone, impure, gray, ...	15′
Stromatopora bed, ...	3′
Limy shale and shaly limestone, ...	5′
Limestone, shaly, gray, ...	10′
Limestone, bluish-gray, rather massive, filled with fossil corals: *Stromatopora; Zaphrentis; Favosites; Atrypa reticularis*, an *Orthis*, and many other shells, ...	25′
Limestone, shaly, with *flint* stones, ...	10′
Limestone, massive, blue (*fossils*), ...	15
Limestone, with many specimens of *Atrypa reticularis*, and flint nodules, ...	20′
Limestone, impure, shaly, filled with *Crinoidal fragments*, *Atrypa reticularis* and *Chætetes*, ...	25′
Limestone, shaly, ...	5′

MIDDLE DIVISION, 90′

(*f*) Limestone, very pure, light-gray, massive, coarsely crystalline, containing many *Crinoidal fragments* (*Quarried*), ...	10′
(*e*) Limestone, dark-blue, rather pure (*Quarried*), . .	25′
(*d*) Limestone, dark-blue, not so pure, .	15′
(*c*) Shales interbedded thinly with bluish-gray limestone layers, ...	15′
(*b*) Limestone, blue massive, ...	5′
(*a*) Limestone, blue, thin layers (*Once quarried*), ...	20′

*The preceding pages have been taken verbatim from Mr. d'Invillier's Report F3 on the four counties.

No. VI, Lower Helderberg (Lewistown) Limestone sections. I. C. White



CXXIII.

LOWER DIVISION, 170′

Shaly, impure, gray limestones,	20
The same seen in the remaining distance down to the assumed top of the Salina formation,	150′

Total at Powell's quarries,	393
Total as measured along Coffee run,	378′
Total of one section in Penn township,	340
Total of another section in Penn township,	350
Total as measured near McConnellstown,	351

The *Stromatopora bed*, first studied in Pike and Monroe counties, and then in Columbia, Montour and Northumberland, appears in nearly all the exposures in Huntingdon county and in precisely the same geological position.

The limitation of *good* limestone beds to the *Middle division* is of great importance to those who design to open quarries. Where Warrior's ridge is unbroken these beds can only be reached by tunneling through the poor beds of the *Lower division.* The considerable excavations of the Everett Iron Company in Bedford county, which have not yet resulted in uncovering good limestone beds, should be regarded as a warning. The dip is about 45° (into the ridge), and a tunnel must be 300′ or 400′ long to strike the bottom layer of the *good limestone* series. But in the gaps through the ridge these good beds can always be easily opened.

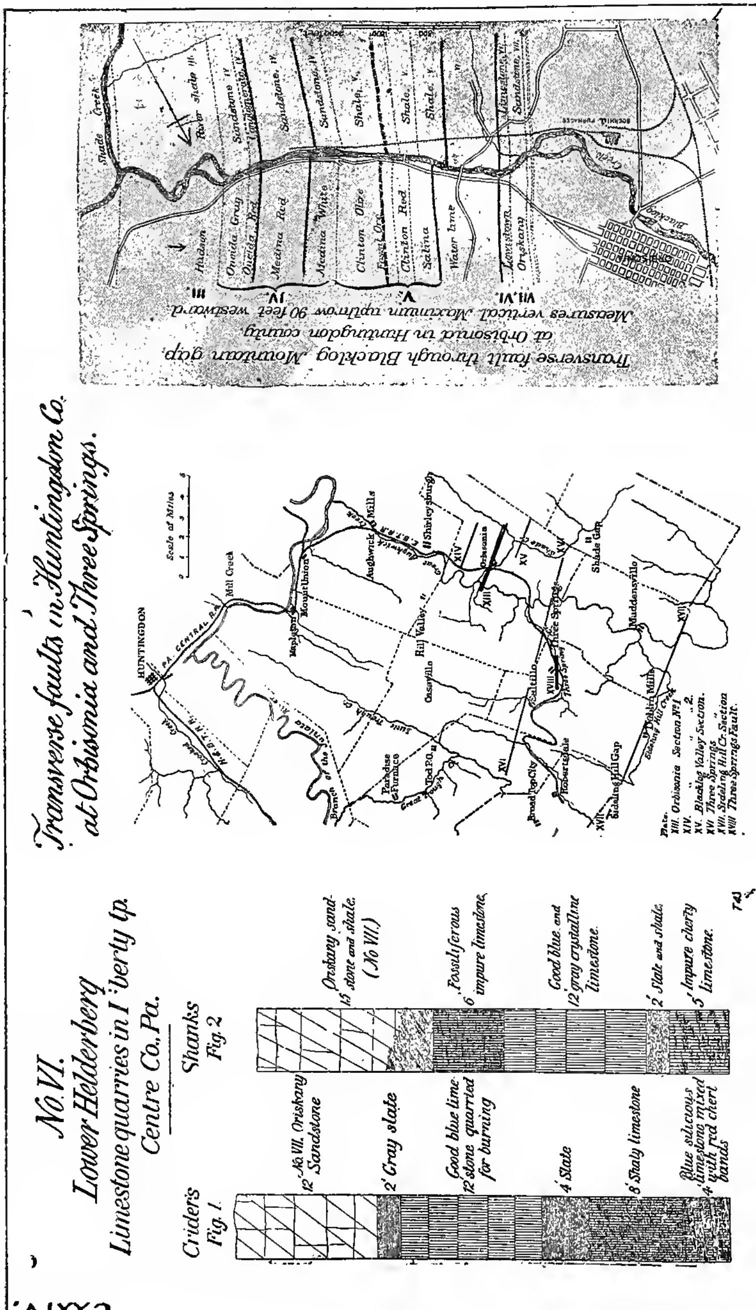
Seldom more than 30′ or 40′ feet of good limestone exists, all told, and in many places not so much.

The principal quarries are at Grafton and at McConnellstown; and on the (*d*), (*e*) and (*f*) beds of the Cove section.

The Grafton (Powell Iron Company's) *quarry-series* is subdivided into—

(1) Top layers of gray crystalline,	10′
(2) Blue,	10′
(3) Cherty (nigger-head limestone),	2′
(4) Ironstone,	4′
(5) Gray,	5′
(6) Blackish,	7′

specimens of which were analyzed by the chemist of the Survey, at Harrisburg, Mr. Andrew S. McCreath.


CXXIV.
No. VI.
Lower Helderberg
Limestone quarries in Liberty tp.
Centre Co., Pa.
Criders
Fig. 1.
12' No. VII. Oriskany Sandstone
2' Gray slate
12' Good blue lime stone quarried for burning
4' Slate
8' Shaly limestone
4' Blue silicious limestone mixed with red chert bands
Shanks
Fig. 2
15' Oriskany sandstone and shale. (No VII.)
6' Fossiliferous impure limestone.
12' Good blue and gray crystalline limestone.
2' Slate and shale.
5' Impure cherty limestone.
Transverse faults in Huntingdon Co.
at Orbisonia and Three Springs.
Scale of Miles
HUNTINGDON
PA. CENTRAL R.R.
Mill Creek
Mount Union
Aughwick Mills
Shirleysburg
Orbisonia
Hill Valley
Cassville
Three Springs
Saltillo
Shade Gap
Maddensville
Robertsdale
Broad Top City
Sideling Hill Gap
Dublin Mills
Paradise Furnace
Plate.
XIII. Orbisonia Section No 1
XIV. " " " 2.
XV. Blacklog Valley Section.
XVI. Three Springs
XVII. Sideling Hill Cr. Section
XVIII. Three Springs Fault.
Transverse fault through Blacklog Mountain gap,
at Orbisonia in Huntingdon county.
Measures vertical. Maximum upthrow 90 feet westward.
III.
IV.
V.
VII. VI.
Hudson
Oneida Gray
Oneida Red
Medina Red
Medina White
Clinton Olive
Fossil Ore
Clinton Red
Salina
Water lime
Lewistown
Oriskany
Shade Creek
Rockhill Furnace
Blacklog

	Upper part of (1)	*Lower part of (1)*	*From (4)*	*From (5)*	*From (6)*
Carb. lime, ...	95.536	98.035	94.642	95.446	93.035
Carb. magnesia, . .	1.589	.908	2.800	1.135	1.816
Ox. iron and alumina,	.490	.410	.370	.520	.730
Phosphorus, ...	.011	.011	.006	.006	.006
Siliceous matter, . .	1.851	.420	1.730	2.350	3.480
Totals, ...	99.476	99.779	99.548	99.457	99.067

Layer (1) is a coarse grayish crystalline rock, almost entirely made up of the broken stems of stone-lilies (*Crinoids*), like bed (*f*) of the Cove quarries; in fact, the top bed of the quarry-series is always of this character, and is preferred to all others by furnace men. Layer (2) however makes the whitest lime. They are all largely quarried for ballast by the Pennsylvania railroad near where the Oneida and West township line comes to the river above Huntingdon. Their belt of outcrop is the richest farming land, and the rock when burnt is a mine of wealth to the farmer.

The upper half of this formation is quite rich in fossils, but no systematic collection of them was made.

[In the Aughwick valley, Mr. Ashburner's section in Report F, p. 241 of rocks beneath the Oriskany shows the following descending sequence, to the bottom of the *Bloomsburg red shale*, amounting in all to 1302′.

LEWISTOWN LIMESTONE, 162′

Limestone, { shaly beds, crystalline beds, }	30′
Limestone, massive, dark blue, crystalline, ...	42′
Limestone, bluish-gray, partly conchoidal, ...	20′
Limestone, blue and brownish-gray crystalline alternating with gray shaly limestone, ...	20′
Limestone, gray crystalline, and dark-blue clayey, with occasional layers of light-gray shaly, and lime shales, containing *Acervularia, Alveolites minima, Astylospongia inornata, Merista arcuata, Merista levis, Orthis oblata, Pentamerus galeatus, Rhynchonella formosa, Atrypa reticularis, Aulopora, Conophyllum, Stromatopora, Trematospira formosa, Zaphrentis*, ...	50′

WATER-LIME CEMENT BEDS, 580′

Limestones, thinly laminated, blue and gray (partly concealed), ...	150′
L. thinly laminated, more massive, bluish-gray, clayey, (conchoidal fracture), ...	110′

L. massive, dark-gray and bluish-gray ; surfaces carbonized, slickensided ; cleavage marked ; calcite ; fucoids ; bivalves,	30′
L. ditto, with lime shales, ...	90′
L. massive, blue-gray, alternating with L. slaty, clayey, and green and yellow lime shales, } . . .	50′
Lime shales, clayey, yellow, gray (partly concealed), . . .	60′
L. slaty, clayey, gray and blue-gray ; and shale, ...	20′
L. thinly laminated, clayey, blue and yellow, Lime shales, gray, alternations, }	20
L. slaty, brownish-gray ; seams of calcite, ...	30′
L. slaty, bluish ; and lime shales, ...	20′

The uppermost (30′+42′+20′=92′) of these belong with Prof. White's *Stormville shales;* the next 20′ corresponds to the first 14′ of his *Lewistown limestone* series ; the next 50′ full of *Stromatopora* and other fossils, to his *Stromatopora bed* 3′ and the 5′, 10′ and 25′ (=43′) beneath it.—His *middle (quarry) division* begins 115′ beneath his *Stromatopora bed* consequently in the middle of Mr. Ashburner's top 150′ of Water-lime series.—His *lower (poor limestone) division* begins 205′ and ends 375′ beneath his *Stromatopora bed;* consequently corresponds to Mr. Ashburner's 110′ (say 75′+110′+30′+90′+50′=say 355′).—All below this in Mr. Ashburner's section above, viz: 60′+20′+20′+30′+20′ (=150′) of shales and lime-shales are transferred by Prof. White to his *Onondaga (Salina)* formation.

Continuing the Aughwick valley section (in F, pp. 241, 242 and 248) before taking up the *Salina series* along Warrior's ridge we have :*

Lime shales, clayey, yellow, brown, gray, green, ...	20′
Lime shales, olive and gray (partly concealed), ...	50′
Limestone, shaly, gray, with olive lime shales, ...	100′
Lime shales, yellow, green, gray and olive ; *alternating with red shales,*	270′

In Bedford and Fulton counties No. VI is described by Prof. Stevenson in his Report T2, page 87, in three subdivisions. On the Maryland State line, these sub-divisions measure 1247′; and on the Bedford and Chambersburg turnpike 1320′, thus :—

* All that is here given on Huntingdon county is copied verbatim from Prof. White's Report T3.

No. VI on the Maryland state line.

VI *c.*	Limestone, mostly massive, (Lewistown limestone),	336′	1247′,
VI *b.*	Limestone, flaggy, cement beds,	283′	
VI *a.*	Shales and thin irregular limestone,	628′	

No. VIc. Hyndman section.

1.	Dark blue fall flaggy limestone,	40
2.	Shaly limestone,	20′
3.	Flaggy limestone,	25
4.	Gray massive limestone,	20′
5.	Dark blue limestone,	22
6.	Gray limestone,	12
7.	Blue irregularly-bedded limestone,	37′
8.	Flaggy limestone,	25′
9.	Gray and blue limestone,	40′
10.	Flaggy limestone,	25′
11.	Gray limestone,	45′
12.	Cherty limestone,	25′

No. 1 underlies the *Silicious limestone* or transition bed which has been referred to the Oriskany.

The gray limestones are semi-crystalline and yield lime of decided excellence. They are quarried at many localities in both Bedford and Fulton, supplying the flux for the furnaces, and lime for farming and building purposes.

Nos. 4, 5, and 7 are fossiliferous at Hyndman; but, except in No. 7, the forms are indistinct, as they have not been silicified, so that a weathered surface shows only their sections. *Stromatopora* occurs plentifully everywhere at the place of No. 7. The fossils are more distinct further north. *Zaphrentis*, *Favosites*, *Orthis*, *Rhynchonella ventricosa*, and *Pentamerus pseudogaleatus* were found in the higher layers, while lower down occur forms characterizing the *Delthyris Shaly Limestone group* at Schoharie, New York.

It is sufficiently clear from the distribution of the fossils that this *upper division* VIc represents the massive limestone of New York. Patient collecting of fossils in the vicinity of Bedford Springs would no doubt yield material for close identification of the New York sub-divisions.

This portion of the group is fairly well shown at many places along the west foot of Will's Mountain. It is the main body of Knobbly mountain in the Bedford synclinal, where partial exposures were seen frequently; it is exposed to a greater or less extent in every gap through Warrior ridge; fair exposures are shown in the vicinity of Fort Littleton and on Cove creek in Fulton county. The features are the same everywhere within the district.

Iron ore occurs in this sub-division.

The *middle division* VI*b* represents the *Tentaculite limestone* of New York, which is perhaps the upper division of the *Waterlime.* It is nowhere exposed in detail, but it consists mainly of blue to very dark blue flaggy to slaty limestones, mostly non-fossiliferous. The darker limestones are fetid when struck and ring sharply. Some reddish beds near the middle of the mass are not flaggy but thick-bedded. Partial exposures of this division were seen at Hyndman and elsewhere along the west foot of Will's mountain; a very fair exposure was found in Cumberland Valley township of Bedford county, where the thickness as given was measured. An imperfect exposure was seen on the Bedford and Chambersburg pike west from Everett, and another, further north, on Piper's run. No good exposure was found in Fulton county. *Leperditia alta* and *Holopœa antiqua* were seen on Piper's run; *Beyrichia*, *Spirorbis*, *Leperditia alta*, *Spirifera vanuxemi*, and *Megambonia aviculoidea* were seen in Bedford borough. All of these forms are characteristic of the *Tentaculite limestone.*

The *lower devision* VI*a* consists of drab to reddish calcareous shales with thin streaks of limestone. The Cumberland road south from Bedford lies for most of the distance on this division. Imperfect exposures were seen on the Bedford and Chambersburg pike in Black valley, as well as at many localities further south in that valley. This division is fairly well shown in Fulton county near Fort Littleton, and it is the immediately underlying rock of Pigeon Cove in that county. Toward the bottom it contains an irregular and impure limestone which is quarried for agricultural uses at some localities. The only fossil seen is *Leperditia.*

Chapter LXXII.

No. VI in Blair, Centre, Clinton and Lycoming counties along the Bald Eagle Valley.

In Blair county, a well was bored at Altoona through 50° dipping rocks and the record gave 192′ limestone, 231′ slate, 557′ limestone (980′ in all) stopping in limestone, and therefore leaving an indefinite additional thickness unknown.*

Mr. Sanders' measurements of exposures of VI in Blair county gave 1130′, thus:

Limestone, mostly dark blue, massive,	900′
Limestone, gray, slaty,	120′
Concealed strata,	30′
Slate, gray with some limestone beds,	60′
Slate, dark gray,	5′
Limestone, slaty,	14′
Limestone,	1′

Considering the great thickness of No. VI in Blair and Bedford counties it is a great pity that no wells behind the Allegheny mountain in the western counties of the state can ever go deep enough to give us a record of its condition underneath that great great expanse of country. For it plunges vertically or very steeply down along its Bald Eagle outcrop to a depth of nearly 12,000′ beneath the lowest coal bed of the Cambria and Clearfield region.†

*There was some doubt about the dip; it may have been 41°; in which case the total of limestone and slate passed through, or into, would be 1183.′ A strong odor of something like petroleum was got at a depth of 1600′ in the well, *i. e.* 300′ geologically beneath the top layer of the lower limestone allowing the dip to be 52°. This might show the horizon of the coral reef. Report T, 1881, p. 37.

† When No. VI comes again to the surface in middle Ohio it is so thin that there seems to be some doubt about recognizing it in the top layers of the "Cliff Limestone" in Montgomery, Highland, Adams and other counties of that state. In the northern part of Highland, at Greenfield, it is recognized, but is only 100′ thick. Towards the Ohio river it thins away and vanishes; the so-called Niagara limestones beneath it being 275′ and the Clinton 50′ (Geol. Ohio, 1870, p. 256, 307). In Tennessee Safford's Meniscus Limestone is shown by its fossils to be of Niagara age (See Geol. Tenn., 1869, p. 315). Over it No. VI is found 25′, 50′, 75′, and probably in some places 100′ thick, in Middle Tennessee, but it is not found in East Tennessee (Geol. Tenn., p. 322).

Its outcrop on account of its steepness is never more than half a mile wide and usually much less. Starting for convenience at Tyrone City, it makes the ridge back of that place; crosses the P. RR. between Topton and Astoria; keeps in the bottom of the valley east of the RR. past Altoona under Allegheny furnace, and down the creek to Duncansville; south of this it spreads out into a triangle. Then it curves N. E. along the top of the ridge between Hollidaysburg and the Reservoir, and passes close to Frankstown up into the Scotch Valley Cove to Beaver Dams. Here it broadens out and runs N. to Frankstown; curves W. and S. around the foot of the mountain; passes under the lower end of the Reservoir; then runs 20 miles straight in front of Dunning's mountain into Bedford county, and so on to Maryland; only that a similar triangle is made by it on the Bedford county map north of Bedford.

The rock is often rough and cherty; always full of fossil shells and corals; especially rich in crinoidal stems and scattered discs, in fact a fossil coral reef. The Water-lime or hydraulic cement beds show coaly coatings and impressions of sea weeds and bivalve shells, most of all *Cytherina* (now *Leperditia*) *alta*, which ought to put them into No. V. These Water-lime beds are 200′ thick in Bedford and Blair, but only 50′ in Lycoming.*

At Tyrone the limestone beds of No VI are more than 780′ thick and make a ridge crowned by the outcrop of the Oriskany sandstone No. VII. Near Tipton a small synclinal roll broadens the outcrop near Elizabeth furnace, in which Trout's and Baker's brown hematite iron ore mines are held. Again near the Bedford county line a small synclinal roll does the same.

The famous *Celestine beds*, near Bells mills, in the bank of the Juniata, are lens-shaped masses between the very

*The underlying grey marls, with thin black clay limestone layers and fissile slate partings, have also massive *magnesian* cement beds (quarried for hydraulic lime at Cumberland, Md.), but no fossils except *Leperditia alta* and *Beyrichia seminalis*, both of them minute crustaceans characteristic of No. V and its fossil ore beds.

bottom-most limestone beds. The red Salina shales appear not 30′ away (T, 128).*

On the old railroad from Baker's ore mine a quarry shows the limestone beds much contorted and crushed, with opposite dips of 20° and 70°, with three faults, one clean up and down, and the other two sliding thrusts. Near Allegheny furnace is a fine vertical section of beds 12″ to 18″ thick dipping 36° (N. 60° W.), almost every layer of the 151′ visible being more or less fossiliferous, (See section in detail in T, p. 129).

Three analyses (by S. S. Hartranft, aid to Mr. McCreath in the Laboratory of the Survey at Harrisburg) show remarkable evenness of constitution in the upper, middle and lower limestones in this Baker's quarry:—Carb. lime, 95.664, 95.089, 95.571; carb. mag., 1.547, 1.581, 1.521; ox. iron and alum., 0.842, 0.644, 0.570; sulphur, 0.103, 0.029, 0.027; phosphorus, 0.015, 0.020, 0.009; insoluble residue, 2.500, 3.000, 3.020, (T p. 129).

The Cambria Iron Co.'s Cresswell quarry, 2 m. N. W. of Hollidaysburg, is in not very fossiliferous beds 2′ thick or more, rather twisted, dipping 50° to 80°, with such quantities of calcite that single masses of a ton are blown down. The blue limestone is extremely pure, the Birdseye kind analysing 97.32 and the Calico kind 97.82 of carbonate of lime. At one time this quarry shipped 250 to 300 tons daily to the Johnstown furnaces.†

The Baker limonite ore mine 3 m. N. E. of Altoona, an open cut 600′ long, 400′ broad and 135′ deep, with a draining and adit tunnel 20′ deeper, which passed through 225′ of solid limestone dipping 63°, S. 70° E. is excavated in a narrow synclinal of No. VI. The cavern was filled with iron ore bearing clays at the top, 25′; black clay with much

*Dr. Genth says in his Report B, 1875, p. 146, that only one variety of this *Celestite* (Dana), crystallizing in the form of *barite*, has been observed in the State. It here occurs in thin seams of a pale grayish blue color and parallel fibrous and columnar structure. It was analyized by Klaproth in 1797; *Stroutia*, 42; Sulphuric acid, 58.—See also McCreath's analysis of the Blair Co. *Barite*, Vol. 1, page 447 above (extracted from his Report M2, p. 369).

†Other large quarries near Hollidaysburg fluxed the Blair Iron Co. furnaces.

pyrites, 15′; clay and flint, 5′ to 10′; bluish black and slate-colored clay, 12′ to 15′, and at the bottom a mass of ore-bearing clay which at one place is at least 44′ deep. At other places along the outcrop pipe ore was mined. The Blair open pit, 250 yards N. E. of the Baker mine is 350′ long, 350′ wide and 60′ [deep; a shaft 100′ deep from the surface yielded lump ore. The Elizabeth mine, ¼ m. N. E. of the Blair was similar. Three other mines N. E. of the last along the ridge of VI, includes Bell's, worked by a shaft and cross cuts.* Mr. Bell's theory was that the ore was in a tightly compressed synclinal fold. The same ores have been opened on the Cemetery ridge of VI at Tyrone. Some mining has been done along the outcrop of VI S.W. of Holidaysburg. The ore is only heavy at the points above mentioned, and its horizon seems to be at the top of VI beneath the bottom of VII. See Report T, p. 135.

Across Centre county No. VI makes an almost perfectly straight outcrop line 45°, N. 45° E. along the N. W. foot of the Bald Eagle mountain, as an inconspicuous terrace, marked by occasional old quarries formerly worked for charcoal furnace flux, as at Unionville, Milesburg and Curtin's, yielding mostly a poor argillaceous limestone, in places cherty. The dip is usually steeply N. W.; at Unionville overturned to 74° S. E. where the ridge furnishes fossil corals and *Atrypa reticularis;* at Milesburg, 34° N. W. in an old quarry, and 70° N. W. on the railroad; at Curtin's, dips of 45° to 80°, N. W. *Strophomena rugosa*, *Spirifera perlamellosa* (?), *Trematotospira* (?) and *Zaphrentis* have also been collected by Prof. Ewing, of the State College (T4, p. 430).†

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*A diagram section of the vertical limestone and ore here mined will be found at the bottom of Plate CXXXI, in a future chapter describing Formation No. VII. It is taken from F. Platt's Report T.

† Nothing can be seen of the outcrop in the divide near the head of Bald Eagle creek, in Taylor township, which borders on Blair. In Worth township it is covered with a mass of boulders of Medina from the mountain side. Nor do any ravines exist in Huston township to expose the beds of V and VI. In Union township VI is exposed at Alexander's quarry south of the creek, shaly, impure, somewhat fossiliferous, dipping 50° N. W.; and in Fisher's two quarries. In Boggs township the Oriskany first appears

Across Clinton county the outcrop of No. VI broadens to the Susquehanna, which flows in it from Lock Haven to Lycoming county.*

(going east) capping the limestone, of which good sections are exhibited in two mountain gaps, and it is quarried back of Milesburg; it makes a decided terrace half way up the mountain, the dip in the gap being 50° to 80° N. W. Prof. Rogers speaks of it in Swoyer's quarry, where a crumple is visible. Approaching Curtin's rolling mill its ridge becomes prominent again, but the beds are thin, siliceous, and without fossils, but the whole formation VI nearly 1000′ thick. Opposite the Old Furnace they dip 78° N. W., only 60′ of beds blue and siliceous being exposed. Here about 100 tons of lean limonite ore was once got from a decomposed slate 3′ to 5′ thick. Near by lies a pile of red slate and ore. (For other such items, see Report T4, p. 283.) Further on the limestone beds are often exposed in the banks of the old canal.

Across Howard township the railroad runs along the outcrop of VI, which is however mostly hid beneath local drift from the Bald Eagle mountain ravines; nowhere making a ridge, although capped by Oriskany. There is a beautiful feature of topography here exhibited by all the ravines; they cut down from the crest to the terrace, then slide N. E. and issue below further east than their starting points (T4, p. 292).

In Liberty township, *Crider's quarry* shows 12′ Oriskany sandstone over 2′ grey slate, 12′ good blue limestone quarried for burning into lime, 4′ slate, 8′ slaty limestone, 4′ blue siliceous limestone mixed with red chert bands; all dipping 26° N. 28° W.—*Shank's quarry* shows 15′ of VII over 6′ impure fossiliferous limestone, 12′ good blue and grey crystalline quarry-rock, 2′ slate and shale, 5′ impure cherty limestone. (See columnar sections in Plate XI, T4, p. 296.) Neither quarry furnishes any good fossil casts. On the hill road from the creek the limestone outcrops are full of fossils, 100 yards west of the school house.

* *In Beeeh Creek township* are few exposures of it.—*In Bald Eagle township* No. VI is sectioned by Fishing Creek gap coming from Nittany Valley through Mill Hall gap. The quarry at the mouth of the gap, old, but not very large, exposes 25′ of hard massive fossiliferous beds dipping nearly vertical N. W. but probably of *Niagara* age. The Block and Fossil ores were both opened here. No. VI makes a synclinal roll in the hill in front of the gap with dips of 5° to 20° S. E., and two old quarries are here in it.—*In Allison township* the two quarries a mile east of Lock Haven seem to be in the Niagara.—A notable exhibition here is of large veins of *calcite*, sometimes 18″ thick, traversing the rocks along the cleavage planes, often enclosing large *water-worn pebbles* and more or less triturated fragments of limestone, which can only be accounted for in one of two ways: Either the river has washed them into the crevices when flowing at an elevation 40′ or 50′ higher than it now reaches; or, subterranean waters have handled them. The dip is 35° to 45° N. W. (G4, p. 45).—In Baird's quarry, still in use, a curious crimple, produced by the settling and sliding of the upper layers on the lower, is shown by Mr. Chance in Fig. 5, on p. 46 of his Report G4. The fracture produced can be followed along a bench on the hillside for some distance.—Between Lock Haven and Mill Hall is a quarry which may

In Lycoming county the outcrop of VI follows the Susquehanna river, seldom making any mark on the topography, being dissolved to and often far below water level, and covered with drift stuff brought down by Pine creek, Lycoming creek and Loyalsock creek from the Allegheny mountain highland in the north.

But in the larger bends of the river long spurs of the Bald Eagle mountain slope (projecting northward) lift the rocks of VI above water level, and in them quarries are opened here and there.

The lime-burning industry of Lycoming county is considerable, and quarries of No. VI limestone are dotted along on the map from Pine creek to Muncy; but only a few of them are of notable size. On Pine creek lime is largely burned.* About 1½ m. W. of Montoursville there are extensive quarries and kilns.† Other quarries exist as far east as Muncy. In White Deer valley there are quarries along a ridge four miles long.‡

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be in No. VI.—*In Woodward township* the limestone exposed and faulted on the canal near Lockport seems to be Marcellus VIII b.—*Across Dunstable and Pine Creek townships* the limestones are impure; but good exposures of No. VI on Pine creek show two overturned anticlinals of considerable size (see Fig. 6, G4, p. 53), which quadruple the breadth of the outcrop along the valley of the West Branch. Here are exposed under soft lime shales 100′ of hard massy argillaceous limestone, 50′ of black lime shale, 150′ of shaly impure limestone with some good beds. Drift covers everything west of the creek.

*Bailey's quarry at the mouth of Pine creek yields a fine grained bluish-grey hard brittle rock of conchoidal fracture, analysing carb. lime 72.2; carb. mag. 20.3; ox. iron and alum 1.6; sulp. 0.2; phos. 0.005; insol. 5.6.—Fergusson's quarry rock, 1½ m. distant, gave carb. magnesia 31.0; sulp. 1.3; phos. 0.003; insol. 7.—In strong contrast with this *dolomite* stands an analysis of an outcrop specimen from the Wilson place back of Jersey Shore showing carb. mag. only 1.740, but with the insol. matter 21.7 (F. Platt, Rep. G2, page 157, 1880).

†At Hoerner's large quarries the massive blue beds dip 12° N. 100′ thick, of which 45′ are quarried. Altogether this group of quarries afford 200,000 bushels of burnt lime annually (F. Platt, 1880).

‡These are in the lower layers of VI. Peter Buck's quarry, 1½ m. N. E. of Elimsport, has a 35′ face of 1″ to 2′ layers burned to good soil lime. Another 2 m. distant shows the same. Another is near Haines' grist mill. No fossils were seen in any of these.

Chapter LXXIII.

No. VI, Lower Helderberg fossils.

From the collections made in middle Pennsylvania Mr. C. E. Hall formed the special collection for study catalogued in Report O3, 1889, pp. 203 to 208.*

In C. E. Hall's catalogue are named the following genera and species:—*Acervularia communis*, Simpson; *Alveolites explanatus* (?) one incrusting a *Chonetes*, another in company with a branching *Cladopora; Alveolites niagarensis*, Rom. (doubtful identification, tubes looking somewhat like those of sponges); *Astylospongia inornata* (15 examples all found near Orbisonia); *Atrypa reticularis* (at several stations, more or less well preserved, sometimes in fragments, sometimes mixed with fragments of other species); *Aulopora schohariæ* (at Orbisonia); *Callotrypa heteropora*, (or a bryozoan closely resembling that New York species) found in Barre township, Huntingdon county; *Camarium typum* (one whole, and many others in fragments, at Orbisonia); *Chætetes* (obscure); *Chonetes punctatus*, Simpson, Dec. 1888 (from Carbon co.); *Cladopora rectilineata*, Simpson (Proc. A. P. S. Dec. 1888; at Tyrone, Blair co.); *Cladopora cespitosa* (or one nearly resembling that Niagara species in New York; found in Barre township, Huntingdon co.); *Cladopora*, a branching species with cells arranged in regular order, 8 rows in a branch,

*Those from Orbisonia in Huntingdon, and Tyrone City in Blair, were collected by C. E. Hall, H. Hale, W. A. Fellows and C. E. Billin; those from Bushkill, Pike Co., by Hall and Fellows; those from Hazardville, Carbon Co., by Fellows and F. A. Genth, Jr. No thorough systematic collecting was ever done anywhere except by Prof. Claypole in Perry Co.; but Prof. I. C. White made collections in his districts which he studied for his own reports and included in Prof. Claypole's catalogue, of which a description will be found further on (See page ——). The fossils published in Report O2, 1880, were studied and their catalogue names revised by G. B. Simpson very thoroughly and the doubtful cases submitted to Prof. James Hall either in Philadelphia or in Albany, and the thus revised catalogue was published in Report O3.

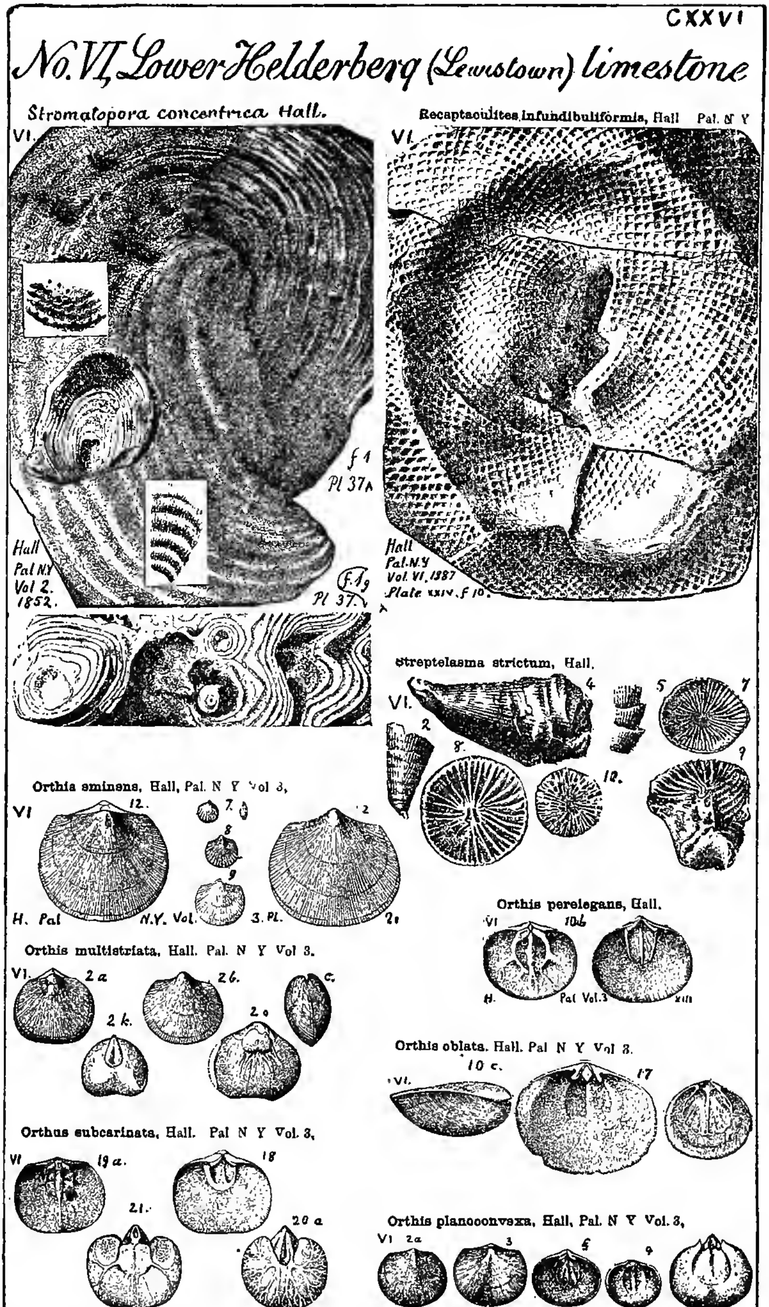

CXIX
No V.b, Niagara Limestone fossils concluded.
Vb.
Lichas bravicepe, Hall.
Dalmanites verrucosus. (Hall,
V, b.
Ind. 1881
IND.
1881
No. Vc, fossils of the Salina or Onondaga.
Atrypa — ? Hall,
V.c
54 6
Avicula triquetra.
V c
54 7
Euomphalus sulcatus.
V.c
H.54 4.
Modiolopsis rhomboidea,
V-VI 203
Eurypterus remipes.
V.c
E. 17.
No. VI, Lower Helderberg limestone fossils.
Chætetes (Monticulipora) abruptus.
VI.
Pal. N.Y. Vol. VI. Pl. 9. f. 9.
Atrypa —?
VI.
R 641
Atrypa lacunosa
VI.
Van. 25.3
Lepadocrinus gebhardi.
VI.
25. 4.
Discina discus
VI
H. III Pl. 9
Eatonia singularis.
VI.
263
Eatonia medialis. Van.
VI.
Van. 26.4
Merietella bella (Merista bella?
VI.
H Pal. NY Vol 3 Pl 40.
Vi, VII Hall III
Eatonias.
Merista lævis. (Atrypa lævis. Vanuxem.) Rog
VI.
R 642
26.
Merista sulcata
VI H 58. 5
Avicula rugosa.
VI.
58 2.
Loxonema compectum, P
460
Geol Can 1863
Megambonia aviculoidea.
VI
Vol. 8 Pl 49
Megambonia? cancellata,
V-VI 1209
Daw.
Holopea antiqua.
VI
58. 4.
Leperditia alta.
VI.
58 6
Bucania profunda
VI.
Van 25 2

2 examples from Orbisonia); *Cladopora* like the Niagara *Multipora*); a *Diphyphyllum?* (2 at Orbisonia; and a very large specimen from Barre township); *Dalmania pleuropteryx* (3 tails of this trilobite from Pike county); *Favosites helderbergiæ* (8 examples mostly conical or spherical from Orbisonia, another from Blair co, and 8 from Pike co.); *Favosites canadensis? Heliophyllum caniculum?* (7 from Orbisonia); *Merista typum; Merista (Meristella) subquadrata* (27 examples from Orbisonia); *Merista (Meristella) lævis* (from Blair co.); *Modiolopsis dubius* (from Carbon co.); *Orthis perelegans* (1 young, and 4 others from Orbisonia); *Orthis punctostriata* and *Orthis eminens* (3 from Carbon co.); *Orthis oblata* (Pike co.); *Pentamerus galeatus* (in Huntingdon, Pike; and 5 slabs showing many individuals at Shawnee in Monroe co.); *Rhynchonella altiplicata; Rhynchonella formosa* (3 in Huntingdon, 3 in Pike); *Spirifera cycloptera?* (in Blair); *Spirifera macropleura* (in Pike co.); *Spirifera perlamellosa* (2 in Pike); *Sponges* of undetermined genera and species (3 at Orbisonia); *Stromatapora concentrica* (a large specimen from Tyrone City, Blair co.); *Strophomena woolworthana* (21 examples from Bushkill, Pike co.); *Strophomena rugosa* (3 from the same place); *Tentaculites* (impressions from the same place); *Trematotopora ——?* (Barre t., Huntingdon co.); *Trematospira globosa* (17 from Orbisonia); *Triplesia extans* (11 examples and many fragments from Barre t., Hunt. co.); *Syringopora ——?* (in fragments from Orbisonia);—and a multitude of more or less obscure bryozoa, corals, and shells, many of the bryozoa showing sections but no surfaces, the brachiopod shells crushed into a mass of fragments, and the crinoidal stems all disjointed, as if beaten on a sea beach and floated out into deeper water.

No. VI fossils in Perry county.

Prof. Claypole's collections in Perry co. in 1882, 1883, were made mostly from the Clark's Mills outcrops near New Bloomfield,* where he found species not mentioned in Hall's

* More than 200 localities (called Stations) are given in the Catalogue, Report O3, 1889, most of them in Perry county, but many others in Juniata,


CXXVI
No. VI, Lower Helderberg (Lewistown) limestone
Stromatopora concentrica Hall.
VI.
f 1
Pl 37A
Hall
Pal N.Y.
Vol 2.
1852.
f. 1g
Pl 37.
Receptaculites infundibuliformis, Hall Pal. N Y
VI.
Hall
Pal. N.Y.
Vol. VI, 1887
Plate xxiv. f 10.
Streptelasma strictum, Hall.
VI.
2
4
5
7
8.
10.
9
Orthis eminens, Hall, Pal. N Y Vol 3,
VI
12.
7
8
9
2
H. Pal N.Y. Vol. 3. Pl. 21
Orthis pereiegans, Hall.
VI
10 b
H. Pal Vol. 3 XIII
Orthis multistriata, Hall. Pal. N Y Vol 3.
VI.
2 a
2 b.
c.
2 k.
2 o
Orthis oblata. Hall. Pal N Y Vol 3.
VI.
10 c.
17
Orthus subcarinata, Hall. Pal N Y Vol. 3,
VI
19 a.
18
21.
20 a
Orthis planoconvexa, Hall, Pal. N Y Vol. 3,
VI
2a
3
6
9

list above:—*Beyrichia granulata* and *notata*, *Chætetes abruptus*, *Cypricardinia lamellosa*, *Discina ampla*, *discus*, *Euomphalus profundus*, *Lepadocystites*, *Leperditia alta*, *Lingula centrilineata* and *spatiosa*, *Megambonia aviculoides*, *Meristella bella*, *lævis*, *Modiolopsis dubia*, *Orthoceras longicameratus*, *Rennsellæia mutabilis*, *Rhynchonella mutabilis* and *nucleolata*, *Spirifera saffordi* and *vanuxemi*; as well as the *Strophomena woolworthana* determined by Jas. Hall from the Delaware river outcrops, as already mentioned.*

No. VI fossils in the Montour region.

Prof. I. C. White's collections on the North Branch Susquehanna and at Selinsgrove are included in Prof. Claypole's catalogues in O3, on pages 135, 147, 149. His Lower Helderberg (No. VI) fossils are placed in their horizons in his sections of Grove Bros'. quarry, Mauser's quarry,

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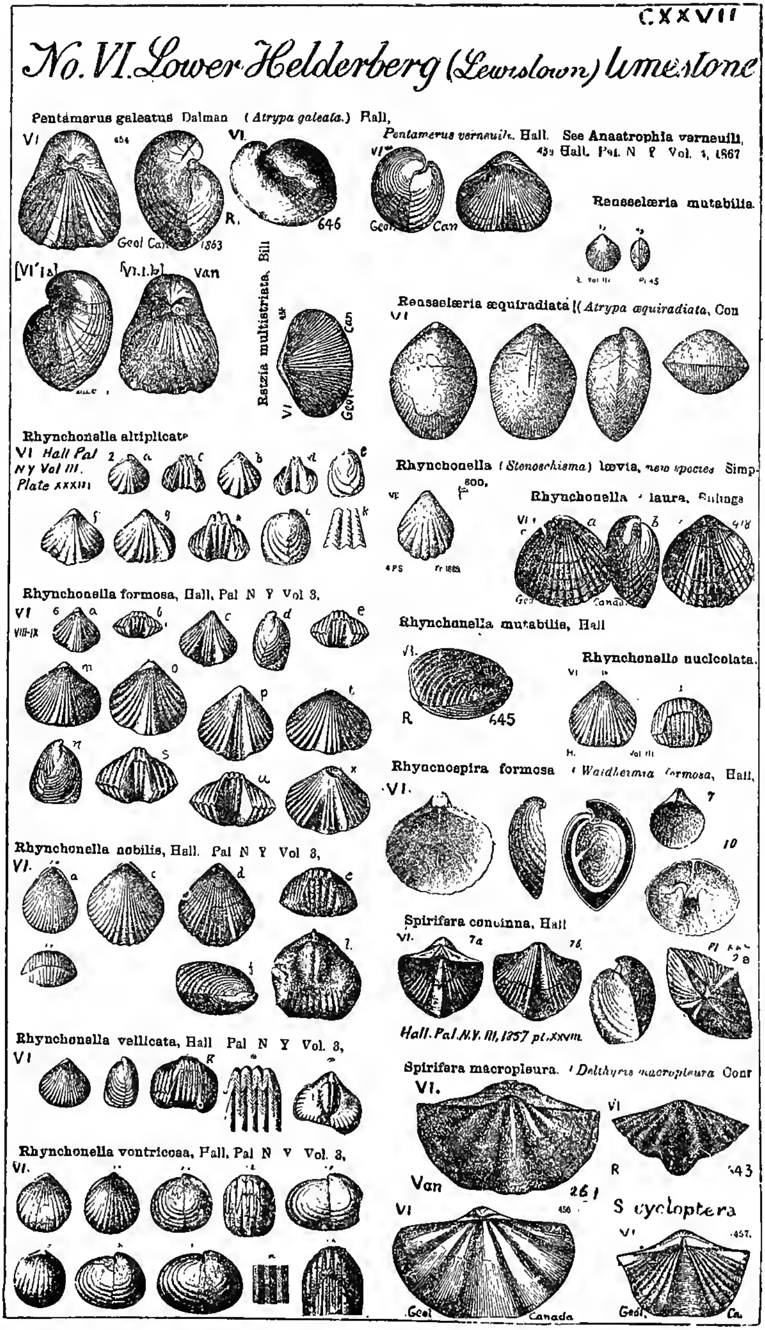
Huntingdon, Northumberland, Montour and Columbia counties. The collection in the last four counties made by Prof. White, are included among Prof. Claypole's, labelled and catalogued by him, and the determinations then used by Prof. White for his reports G7 and T3. Descriptions and figures of new species discovered or suspected by Prof. Claypole were postponed and have not yet been published by the Survey, but are reserved to the Appendix (Fourth) volume of the Dictionary of Fossils. The same is for the most part true of Mr. Simpson's new species a list which is given in Preface to O3, p. 7. — Fossils of VI were collected at Stations at various distances around New Bloomfield; along limestone ridge, in Montebello narrows, etc.

* The palæontologist must consult Prof. Claypole's numerous station catalogues in Report O3, p. 123 onward, which unfortunately are there arranged in a confused geographical order and not in the order of formations; especially the Clark's Mills catalogue on pp. 128, 129. On one slab from the upper shale beds are seen *Tentaculites gyracanthus* and *Beyrichia notata*. There are here noted *Lepidocystites gebhardi*, *Stromatopora* (or *Astrocerium*) and *Astrocerium* in shale.—On p. 130, *Rhynchonella vellicala* and *Platyceras spirale* in the chert beds at the top of the formation; a *Murchisonia* from the shale beds, also *Leptæna rugosa*, *Ambocœlia umbonata*, *Dalmanites myrmecophorus?* Green, with others already cited.—On p. 136, the abundance of the trilobite *Dalmanites* in these upper shales is shown, whereas the lower (Lewistown) beds are full of corals.—On p. 137, *Phacops rana* and *Leiorhynchus limilare* in the Shale beds; and here appear the fish *Bothrilepis taylori* and its coprolites, *Schirodus rhombius*, *Sanguinolites rigidus?* W. and W., *Goniophora chemungensis*, Van., *Granmysia elliplica* and *Palæoneilo barrisii*. On p. 160, *Chætetes abruplus* in the upper shale.—On p. 165, *Stromatopora corallifera?* (here misprinted as in Hamil. ton.)—On p. 166, *Phacops logani*.—On p. 171, *Spirifera octocostata?* Sby.


CXXVII
No. VI. Lower Helderberg (Lewistown) limestone
Pentamerus galeatus Dalman (Atrypa galeata.) Hall,
Pentamerus verneuili. Hall. See Anastrophia verneuili, Hall. Pal. N Y Vol. 4, 1867
Rensselæria mutabilis.
Retzia multistriata, Bill
Rensselæria æquiradiata ((Atrypa æquiradiata, Con
Rhynchonella altiplicata
VI Hall Pal N Y Vol III. Plate XXXIII
Rhynchonella (Stenoschisma) lævia, new species Simp.
Rhynchonella laura, Billings
Rhynchonella formosa, Hall, Pal N Y Vol 3.
Rhynchonella mutabilis, Hall
Rhynchonella nucleolata.
Rhyncospira formosa (Waldheimia formosa, Hall,
Rhynchonella nobilis, Hall. Pal N Y Vol 3,
Spirifera concinna, Hall
Hall. Pal. N.Y. III, 1857 pl. XXVIII.
Rhynchonella vellicata, Hall Pal N Y Vol. 3,
Spirifera macropleura. (Delthyris macropleura Conr
Rhynchonella ventricosa, Hall. Pal N Y Vol. 3,
S cycloptera
Geol Canada

Low Bros'. quarry, Big Fishing Creek, Russells' quarry, Limestone ridge, Selinsgrove and Georgetown, in Report G7, pp. 87 to 94, reduced figures of which I have included in Plates CX, page 740; CXXII, page 754; CXXV B, page 984. The *Stromatopora beds* are perhaps the most interesting feature, and to them I give a separate chapter.

No. VI fossils on the Delaware river.

Dr. S. T. Barrett, of Port Jervis, who studied the formation at the quarries on both sides of the New York–New Jersey State line, especially Buckley's, Bennet's and Nearpass' quarries, made the following classsification of its subdivisions.*

No. 7.	*Trilobite layers;* very fossiliferous,	5' to 10'
No. 6.	Upper shale; fossils,	150'
No. 5.	Upper quarry stone; fossiliferous,	10'
No. 4.	*Delthyris shale,*	120'
No. 3.	*Lower Pentamerus cherty limestone,*	40'
No. 2.	*Favosites limestone,*	2' to 5'
No. 1.	*Tentaculite limestone,* best quality, Lower quarry stone (of Geol. N. J. p. 159,	20'

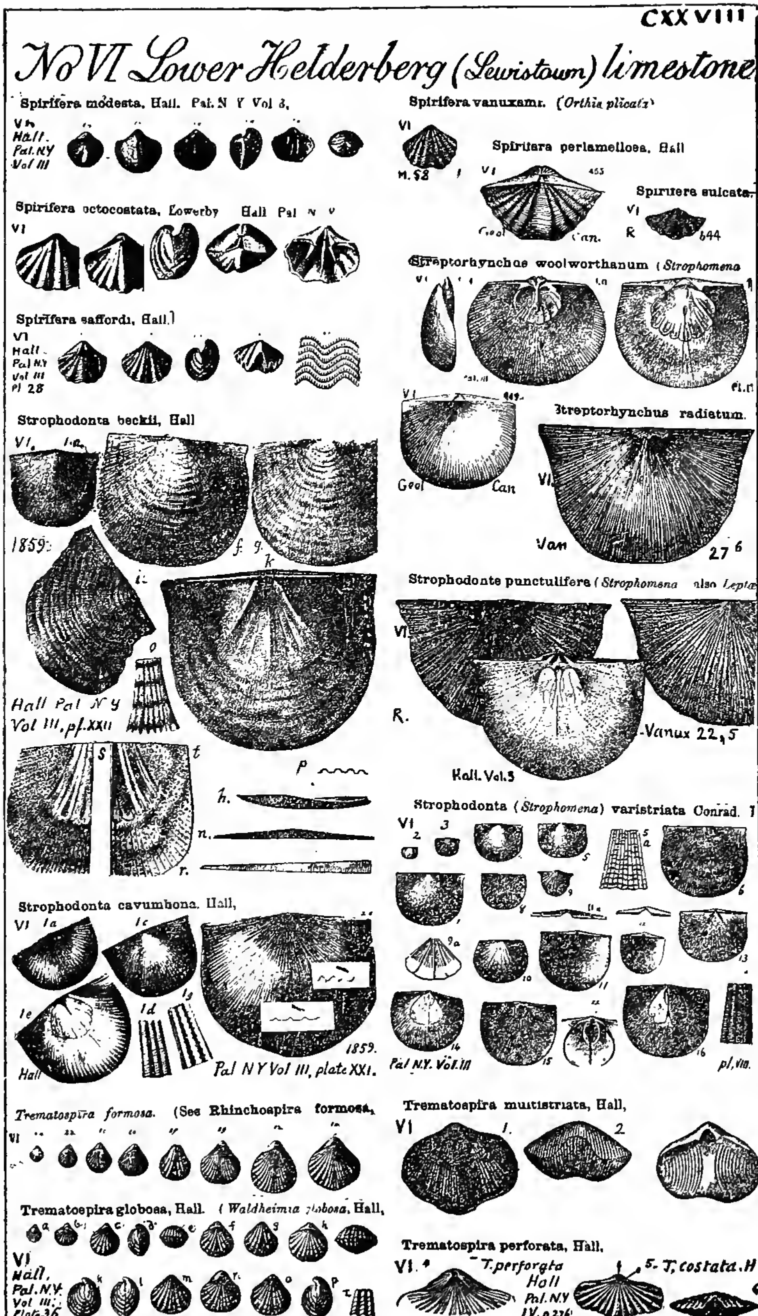
Dr. Barrett's collections were very rich in genera and species, many of which were unknown elsewhere; and many were determined or verified by Prof. J. Hall.

No. 7, the "Trilobite reef" bed, furnished five trilobites: *Homalonotus vanuxemi*, and four species of *Dalmanites* (*pleuroptyx*, *nasuta*, *dentata* and *micrurus*) so named by Dr. Barrett.

Also a little crustacean, *Beyrichia granulifera* (?)—Also the lamellibranch shell *Pterinea textilis;*—the gasteropod shells *Holopea antiqua* and *Lexonema fitchiana;* — the pteropods *Hyolithes centennialis* and *Tentaculites elongatus;*—the brachiopod shells *Chonetes complanata* (the most abundant of the list), *Rennsellæria mutabilis* (next in abundance†); two species of *Strophomena* (*rhomboidalis*,

*Annals of the Lyceum of N. History, N. Y. Vol. XI, abridged in Am. Jour. Arts and Sciences, p. 385, May, 1877. The thicknesses given in the memoir are reduced, conjecturally, in the table of the text above.

† The stony casts of these two shells and of the trilobite *Dalmanites dentata* are so abundant as literally to make up the solid mass of the rock. In Ulster Co., N. Y., south of the village of Rochester, trilobites, especially *Asaphus*, are so numerous in the outcrop of VI that Mather and Horton named the ridge "Trilobite mountain." Geol. N. Y. Mather, 1843, p. 333.


CXXVIII
No VI Lower Helderberg (Lewistown) limestone
Spirifera modesta, Hall. Pal. N Y Vol 3.
Hall. Pal. NY Vol III
Spirifera vanuxemi. (Orthis plicata)
Spirifera perlamellosa, Hall
Spirifera sulcata
Spirifera octocostata, Sowerby Hall Pal N Y
Spirifera saffordi, Hall.
Hall. Pal. N.Y. Vol III Pl 28
Streptorhynchus woolworthanum (Strophomena
Strophodonta beckii, Hall
Streptorhynchus radiatum.
1859
Hall Pal N Y Vol III, pl. XXII
Van 27 6
Strophodonta punctulifera (Strophomena also Lepta
R.
Vanux 22, 5
Hall. Vol. 3
Strophodonta (Strophomena) varistriata Conrad.
Strophodonta cavumbona, Hall,
1859.
Pal N Y Vol III, plate XXI.
Pal N.Y. Vol. III
pl. VIII.
Trematospira formosa. (See Rhinchospira formosa,
Trematospira multistriata, Hall,
Trematospira globosa, Hall. (Waldheimia globosa, Hall,
VI Hall, Pal. N.Y. Vol III; Plate 36
Trematospira perforata, Hall,
T. perforata Hall Pal. N.Y. IV, p 276
T. costata. H

and *conradi*); five species of *Strophodonta* (*cavumbona*, *planulata*, *beckii*, *leavenworthana*, and *varistriata*); two species of *Orthis* (*subcarinata*, and *multistriata*); *Spirifer arrectus*; *Cyrtia rostrata*; two species of *Discina* (*discus*, and *conradi*); a supposed species of *Trematis*; and others that could not be certainly made out.

No. 6 is sparingly fossiliferous.

No. 5 furnishes the gasteropod *Platyceras retrorsum*; and the brachiopod shell *Rhynchonella ventricosa*.

No. 4 furnishes in abundance two species of *Spirifer* (*macropleurus* and *lamellosus*); and many more forms characteristic of the Delthyris shaly limestone formation of eastern New York

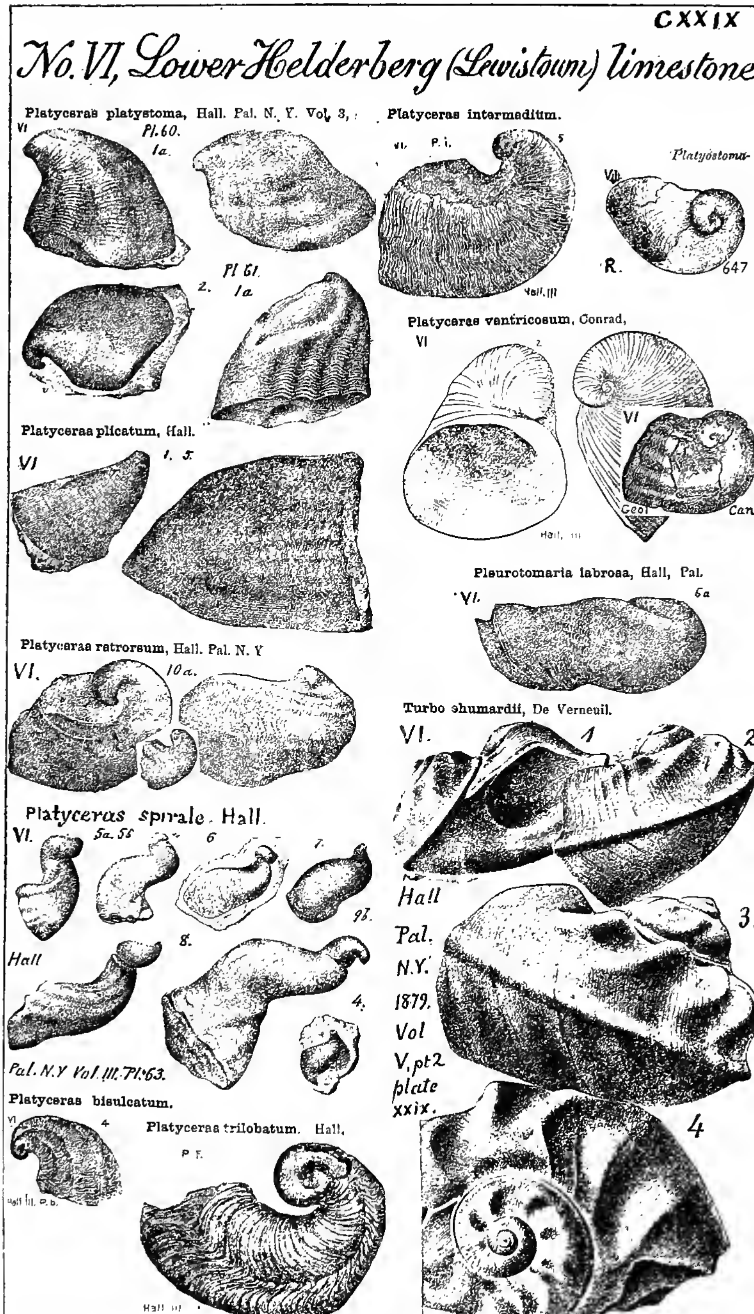
No. 3 furnishes the brachiopod shell *Pentamerus galeatus*; and the same trilobite *Delmanites pleuroptyx* which is furnished by No. 7, three hundred feet higher up in the series.—Also a bryozoan, *Lichenalia*, the species not determined, but unless a new species it must be either *concentrica* or its variety *parvula*, both of them named by Hall from the *Niagara formation*.

No. 2, a coarse brecciated rock, full of the large *coral Favosites helderbergiæ*, mixed with fragments of *encrini* (stone lilies) like the "*Coralline Limestone*" formation of New York, occupies the place of the *Stromatopora* bed of the Pennsylvania sections. Dr. Barrett thinks that he also recognizes the *Niagara* coral, *Favosites niagarensis*. There is also a *Cyathophyllum*.

In this coral reef are buried also many shells:—*Pentamerus galeatus*, *Chætetes helderbergiæ*, *Strophodonta punctulifera*, and others characteristic of the Delthyis shaly limestone formation of eastern New York.

No. 1, the bottom mass of the section, has an abundance of *Tentaculites gyracanthus*, *Spirifera vanuxemi*, *Strophodonta varistriata, and Megambonia ovoidea.**

*This last named fossil is especially important, as it helps to contrast this Port Jervis section at the east end of the State with the Clark's Mill section in Perry county, where (as we shall see in chapter—) *Megambonia aviculoidea* occurs in the lime-shales which overlie the Bossardville (Lewistown) quarry limestone, while the latter contains nothing but *Leperditia alta*. In Perry county the *Tentaculites gyracanthus* is confined to the top bed of the 150′ of lime-shales, F. 2, p. 60.


CXXIX
No. VI, Lower Helderberg (Lewistown) limestone.
Platyceras platystoma, Hall. Pal. N. Y. Vol. 3,
Pl. 60.
1a.
2.
Pl. 61.
1a
Platyceras intermedium.
Platyostoma
R.
647
Platyceras ventricosum, Conrad,
Geol
Can
Platyceras plicatum, Hall.
Pleurotomaria labrosa, Hall, Pal.
6a
Platyceras retrorsum, Hall. Pal. N. Y
10a.
Turbo shumardii, De Verneuil.
Platyceras spirale. Hall.
5a. 5b
6
7.
9b.
8.
4.
Hall
Pal. N.Y Vol. III. Pl. 63.
Hall
Pal.
N.Y.
1879.
Vol
V, pt 2
plate
xxix.
3.
4
Platyceras bisulcatum.
Platyceras trilobatum. Hall.

No. VI. Fossils of the Water lime.

This formation has been variously systematized as the top member of the *Salina* (Onondaga) division of No. V, as a separate formation between V and VI, and by the First Survey of Pennsylvania and the Canada Survey as the bottom division of the *Lower Helderberg* formation No. VI.

The crustacean genus *Pterygotus* confines all its species to this formation, and the crustacean *Eurypterus remipes*, and the lamellibranch shell *Pterinea rugosa* are considered characteristic of it and not found either above or below it along the New York outcrops.*

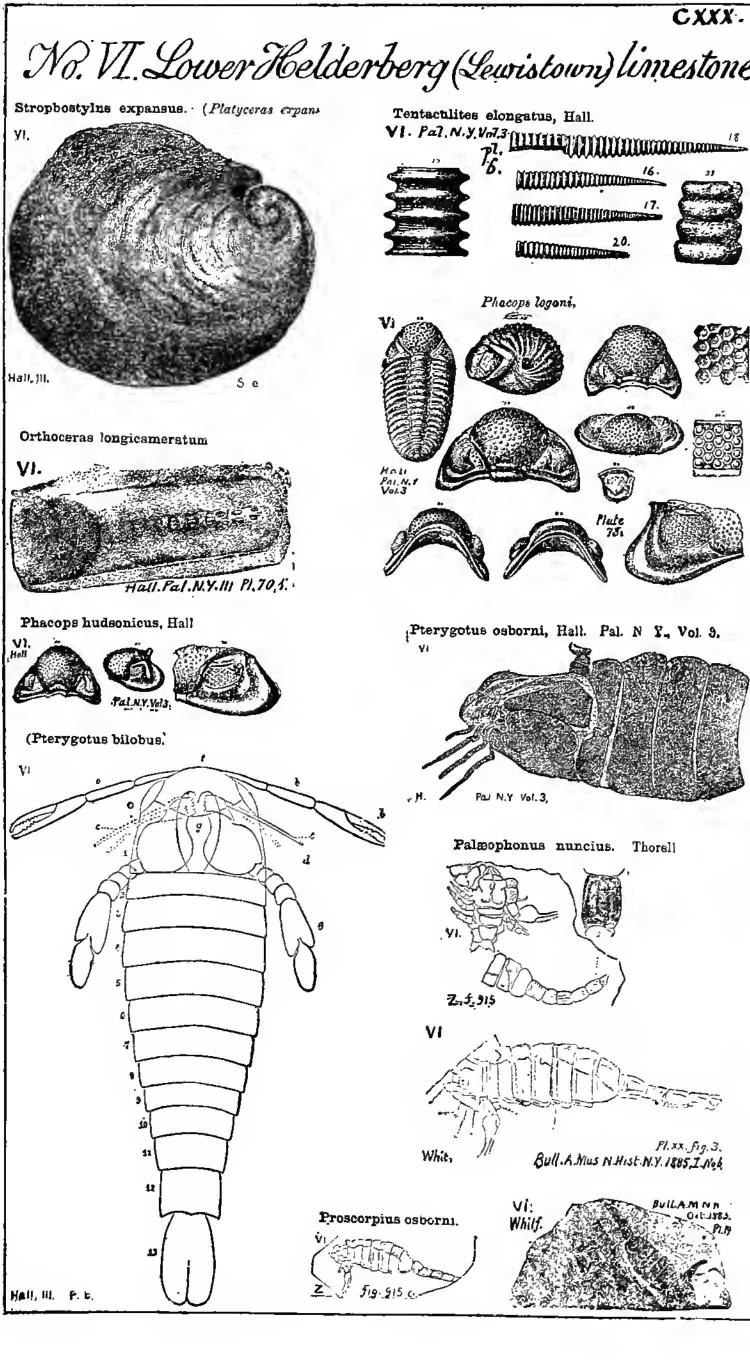
On the other hand it is rather difficult to imagine such a shallowing of the sea in the course of the deposits of No. VI as to admit of the growth of the Stromatopora reefs to be described in the next chapter, supposing them to be of the nature of corals and not of the nature of sponges.

But a still greater objection to the notion of deep sea Water lime deposits was raised by the discovery of *scorpions* in that formation, although it is of course possible that dead land animals may have been swept far out beyond the mouths of rivers and buried in the greatest depths of the ocean. This discovery of earliest air-breathing animals, if these scorpions were such, produced a sensation in the geological world and deserves special attention.

No. VI. The Water-lime scorpion.

A small scorpion was discovered in the Water-lime beds at Waterville, N. Y., in November, 1882, by Mr. A. O. Os-

*S. A. Miller's N. A. Geol. and Pal. 1889, p. 55.—The number and large size of these creatures argue for the possible great depth of the Appalachian Sea in this age, so far as we draw correct inferences from recent deep sea dredgings. For example, crabs and lobsters (decapods) were dredged by the Albatross in the North Atlantic from great depths; one-third of all the species came from 6000′+; five from 12,000′+; one which had well formed eyes; showing that light descends more than two miles through the pure mid-ocean water. At these great depths no small ones were found; all were large; one had a shell 5″x6″; another's legs spread out over more than 3′ of space; some were colorless, most of them were either red or orange. Of 21 deep species eight had normal black eyes; two had very small eyes; three had albino eyes; with the rest it was doubtful whether they had eyes at all. Many of the deep sea species had a small number of very large eggs (S. I. Smith, in Am. Mag. Nat. Hist.—Science, April 9, 1886.)


CXXX.
No. VI. Lower Helderberg (Lewistown) limestone.
Strophostylus expansus. (Platyceras expans
VI.
Hall, III.
Tentaculites elongatus, Hall.
VI. Pal. N.Y. Vol. 3. Pl. 6.
18
16.
17.
20.
Phacops logani,
VI
Hall Pal. N.Y. Vol. 3
Plate 73.
Orthoceras longicameratum
VI.
Hall. Pal. N.Y. III Pl. 70.
Phacops hudsonicus, Hall
VI. Hall
Pal. N.Y. Vol. 3.
Pterygotus osborni, Hall. Pal. N Y., Vol. 3.
VI
Pal. N.Y Vol. 3.
(Pterygotus bilobus.)
VI
Hall, III. F. E.
Palæophonus nuncius. Thorell
VI.
Z. f. 915
VI
Whit.
Pl. xx. fig. 3.
Bull. A. Mus N. Hist. N.Y. 1885, I. No. 6
Proscorpius osborni.
VI
Z
fig. 915 c.
VI:
Whitf.
Bull. A. M. N. H.
Pl. 19

borne,* and similar insects in Scotland in 1883,† and in Sweden in 1884,‡ in rocks of about the same age, or somewhat later (Upper Ludlow). The New York specimen, named by Mr. Whitfield *Proscorpius osborni*, is 1½ inches long with part of the tail missing. The hind legs have double claws as in living scorpions; but instead of carrying his tail curved over his back as the living scorpion does, this ancient scorpion could only bend his tail downward. If this insect lived on land it is the oldest air-breathing animal as yet discovered. But it probably lived in the water; for no breathing holes on its four belly-plates, as in modern scorpions. are indicated in the specimen (which is mashed flat); and the American, Scotch and Swedish fossil scorpions were all three found in rocks which held water crustaceans (*Eurypterus*, *Pterygotus*, *Ceratiocaris* and *Leperditia*). Therefore, although we have reason to believe that the waters of that particular age were comparatively shallow, that islands were here and there laid bare, that coral reefs reached the surface of the sea and were broken to pieces by the waves, and that continental land must have existed, yet it is not safe to say that we have in this *Proscorpius osborni* the oldest air-breathing animal as yet discovered, although that may prove hereafter to be the case. Mr. Whitfield's opinion is rather in favor of its aquatic habits, and that its posterity acquired air-breathing powers and terrestrial habits in course of time; for, the scorpions found in the coal measures and described by Mr. S. H. Scudder were, like the centipedes, spiders and cockroaches found with them, land insects.§

Whitfield's *Proscorpius osbornei* has one leg preserved, which ends in two long parallel claws. All modern scorp-

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*Bull. Amer. Mus. Central Park, N. Y., Vol. I, No. 6, Art. IV, 1885. R. P. Whitfield. Also Science, July 31, 1885.

†Glasgow Herald, Dec. 19, 1884.

‡Comptes rendus Acad. Nat. Paris, Dec. 1, 1884.

§See outline drawing of *Eoscorpius carbonarius* in Dana's Manual, 1880, p. 334; and picture of *Cyclophthalmus senior* from the Bohemian coal measures in Nicholson's Manual, 1872, p. 182, and a picture of *Eoscorpius glaber* from the Eskdale coal measures in Scotland in Giekie's Text Book, 1882, p. 732.

ions have two claws to a foot.* The Swedish and Scotch scorpions have only one claw, or have pointed feet. The little creature is found with Eurypterus and Pterygotus, large swimming lobster-like animals, and may have lived with them in the water; but no spiracles for breathing in water can be seen.†

Land plants existed as is shown by the starry leafed *Annularia romingeri* Lesqx. found by Dr. Roeminger in a sandstone bed of Lower Helderberg age in Michigan. ‡

It is very remarkable that no trace of any fresh or brackish water animals, no *river fishes*, not a single backbone or even disjointed vertebra has as yet been seen from Lower Silurian rocks; nothing but marine remains. Yet one would suppose that the multitude of edible trilobites and other crustaceans would have called into life a sufficient

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*The photographic figure in Plate XIX, Bull. Am. Mus. Nat. Hist. I, 6, O. N. 1885, shows the two claws very plainly. Prof. Thorell, unwilling to believe that a true scorpion lived so early as Upper Silurian times suggests that one of the two may be a side spine, such as appears at the fifth joint of the Scotch scorpion (*Palæophonus nuntius*) described by Peach in Nature, XXI, 796, p. 297, Jan. 1885; and by Thorell & Lindström, in K. Sv. Vetens. Akad. Hand. XXI, No. 9. Thorell objects that the tail could not have curled under the body, when *Palæophonus nuncius* living at the same time curled its tail over its back, like a modern scorpion. See his criticism of Whitfield, in Amer. Naturalist XX, 3, March, 1886, p. 272. Whitfield replies (in Science, VII, 161, March 5, 1886) that he might easily have carried it straight out, as it is shown in the specimen. The whole discussion, involving the question whether the belly plates are seen from under the edge of the back plates, etc., is interesting.

†Prof. S. B. Scudder, the highest authority on Palæozoic insects, in the proceedings of the Amer. Acad. Arts and Sciences, Boston, June, 1884, published a "Contribution to our Knowlege of Palæozoic arachnidæ," in which he describes the new family of the Eoscorpidæ, and its species *Eoscorpius carbonarius*, Meek & Worthen, from the Mazon creek coal measures; *E. anglicus*, Woodward; *E. euglyptus*, Peach; *E. glaber*, Peach; *E. inflatus*, Peach; *E. tuberculatus*, Peach; *Cythophalmus senior*; *Mazonia woodiana*, Meek & Worthen; and adds that other scorpions have been found in the Permian (uppermost carboniferous) strata in Bohemia; and in the tree stumps in the famous Joggins coal measure section in the Bay of Funda.

‡Trans. Amer. Philos. Soc. Phil. 1877, page 166; Dr. Collett's Indiana report of 1883, plate 3; and Dict. Foss. Pa. vol. 1, p. 27.—This genus of swamp reeds continued to produce species (*antiqua*, *dawsoni*, *laxa*) in Devonian times and flourished greatly in Subcarboniferous (*cuspidata*, *radiata*) and Carboniferous times (*calamitoides*, *clavata*, *emersoni*, *fertilis*, *inflata*, *longifolia*, *minuta*, *sphenophylloides*, *tuberculata*.)

abundance of carnivorous fishes to make the concealment of their remains impossible. The head plates of the Lower Ludlow rocks (*Pteraspis*), the defensive spines of the Upper Lindlow bone bed (*Onchus*) and the shagreen scales (*Thelodus*, *Sphagodus*) seem to be good evidence that predatory fishes were really abundant ; but there is no evidence that they had an interior skeleton. The spines were probably on fishes like the now living Port Jackson shark (Cestracionts), and the scales were probably the skin-covering of creatures resembling the now existing Dog-fishes.*

*From the Upper Silurian beds of Bohemia Barrande has described as true fishes *Coccosteus primus*, *Coccosteus agassizi*, *Asterolepis bohemicus*, *Gompholepis panderi*, and *Ctenacanthus bohemieus*, the last one supposed to be a shark. Nicholson Manual of Pal. Lond. 1872, p. 519.

Chapter LXXIV.

The sponge coral reefs of No. VI.

Stromatopora is a beautiful and curious fossil over the nature of which there have been many discussions. It was first described by Goldfuss in 1826. A variety of other kinds have been subsequently figured under various names, so that they form a series of genera, arranged by the last authorities in two groups: A. *Hydractinoid;* B. *Milliporoid;* each containing two families; 1. *Actinostromidæ*, 2. *Labechiidæ*, 3. *Stromatoporidæ*, 4. *Idiostromidæ*; holding fifteen genera; (1) *Actinostroma*, *Clathrodictyon*, *Stylodictyon;* (2) *Labecia*, *Rosenella*, *Beatricea*, *Dictyostroma;* (3) *Stromatopora*, *Stromatoporella*, *Parallelopora*, *Syringostroma;* (4) *Idiostroma*, *Hermatostroma*, *Amphipora*, *Stachyodes*.

These extinct creatures, growing like corals, have been variously regarded as Corals, as Sponges, as Foraminifera, as Polyzoa, and now by most palæontologists as *Hydrozoa*, a class of the jelly-like animals that spread in lichen-like patches, or moss-like tufts over seaweeds, stones and shells, producing buds which develop into medusæ and other free-floating jelly fish.*

*See Monograph of British Stromatoporoids, by H. Alleyne Nicholson (of Aberdeen) in Palæon. Soc. Vol. 1885 (reviewed in Geol. Mag. March, 1886, p. 123). Dawson and Hyatt have regarded *Stromatopora* as a foraminifer like the doubtful *Eozoon canadense.* Sollas, Rosen and Nicholson placed it among *sponges.* Carter (followed by Zittell, Lindström and others) discovered its true relations to the *hydrozoa.* Nicholson collected largely on both sides of the Atlantic, made a thousand transparent slices for the microscope and established the systematic character. He examined Goldfuss' type specimen at Bonn and found it very different from the forms referred to it by geologists elsewhere. The original skeleton of *stromatopora* was granular carbonate of lime (arragonite?) now replaced by calcite, or by silica. The principal feature seems to be *superimposed concentric layers*, made up of vertical rods (radical pillars) united at intervals. The animals lived in the interstices. Nicholson made the important discovery that the skeleton is penetrated by minute, winding, parallel, vertical tubes

The *Stromatopora bed* of the Lower Helderburg formation (No. VI) was an extensive sponge coral reef, of no great thickness anywhere, growing in patches over a great extent of sea bottom. How long a time of growth—years or centuries—the bed represents is not known.

It is difficult to say whether the animal belonged more to the order of *corals*, or to that of *sponges*. It grew in globular, hemispherical or irregularly shaped masses, often of large size, often attached to shells ; in concentric sheets, like an onion, penetrated by minute tubes showing as pores on the surface of the skin.*

There seem to have been many species of it, some of which lived as early as the No. III age, and others contined to live as late as the No. VIII age. Thus we have *S. compacta* (Bill.) in the Canadian Black river shales;—*S. concentria* (or *striatella*) (Gold.) *S. ostiolata* (Nich.) and *S. constellata* (Hall) in the Niagara, Coralline, Guelph and Lower Helderburg limestone;—*S. granulata* (Nich.) *S. mammillata* (Nich.), *S. nodulata* (Nich.), *S. perforata* (Nich.), *S. ponderosa* (Nich.), *S. substriatella* (Nich.), and *S. tuberculata* (Nich.), in the Corniferous limestone;—*S. cæspitosa* (Winch.), *S. monticulifera* (Winch.), *S. nux* (Winch.); and *S. pustulifera* (Winch.) in the Hamilton rocks;—*S. alternata* (Hall), *S. erratica* (Hall), *S. expansa* (Hall), S. *incrustans* (Hall), and *S. solidula* (Hall) in the Chemung

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(not enclosed by walls, but by worm-like fibres, like the tubes of Millepores) and traversed by calcareous plates (as in the Millepores and the table-like corals). *Caunopora* is rejected as a genus, and only "*Caunopora* tubes" (sometimes spiny) are spoken of; they closely resemble those of *Syringopora* and *Aulopora ;* and Roemer, Carter and others have even suggested that they were independent organic beings around whom the Stromatopora animals had grown. Nicholson concludes that *Caunopora* and *Diapora* are combinations of a *Stromatopora* and *coral* (*Syringopora* or *Aulopora*).

* See three fine figures in Hall's Pal. N. Y. Vol. II, pl. 73, p. 325, of specimens from the Corralline Limestone at Scoharie, N. Y. at the base of the Helderberg escarpement, which he considered the eastern representative of the Niagara Limestone of western New York. See also Fig. I5, on p. 71 of Nicholson's Manual of Palæontology, 1872. See also Fig. 51, on p. 240 of Murchison's Siluria, *Stromatopora striatella*, d'Orb. or *concentrica*, a common Wenlock fossil of England. Dana's Man. Geol gives it in f. 428, p. 225.—*Stromatopora rugosa*, Hall, is figured in Mem. Geol. Sur. Canada.

shales;—and *S. verrucosa* (Troost) in undetermined Devonian rocks in Tennessee.*

At this particular stage of the vertical column of rocks it is in a solid bed, and has evidently grown where it is seen and not been brought by waves and currents from some other regions, as is so often the case with the stone-lilies and other corallines usually found scattered and broken up in the rocks as if washed from places more or less far distant. It constitutes a massive bluish-gray limestone 10′ thick, occasionally 15′, composed almost entirely of the *Stromatopora concentrica.*

It was an age of coral reefs. This is evident from the fact that at one place in Columbia county† a bed not five feet lower down a massive gray limestone 20′ thick contains vast quantities of chain-coral *Halysites catenulatus*, or *catenularius*,‡ which Murchison justly calls the "universal coral" of the Wenlock age in Europe, corresponding to our No. V, VI, formations.

The bed beneath this again, a rough gray limestone, is a mere mass of stone-lily (crinoidal) fragments and broken shells; containing also great numbers of two other kinds of coral, *Cladopora multipora* (?) § and *Favosites helderbergiæ.* ||

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* Am. Pal. Fossils, S. A. Miller, 1877, p. 61. The specific names quoted above were invented to indicate the many shapes and ways in which the colonies or reefs of these animals grow, and the various arrangements of skins or sheets and pores which the fossils exhibit:—whether solid, compact, ponderous, expanded, erratic, incrusting, concentrate, striated, alternate, perforated, turflike, starry, granulated, mammillated, tuberculated, pimpled, warty, nodular, conebearing or nutlike. The *S. ostiolata* is so called because its pores look like little doors. But under all aspects, the fossil is unmistakable after being once seen; whatever may be the difficulty of finding it as scattered through the higher and lower formations, it is easy to find it and to collect any number of specimens of it along the outcrops of No. VI, under the Oriskany sandstone No. VII.

† Mauser's quarry section, Columbia co., G7, p. 89.

‡ See *Halysites catenulatus* in Dana's Man. Fig. 425, p. 225; and Murchison's Fig. 19 in Siluria Wenlock formation, p. 133.

§ This species is supposed to be characteristic of the Niagara. See Hall. Pal. N. Y., II, 1852, Pl. XXXIX.

|| Described in 26th Reg. Rt. New York State Survey for 1874, pp. 111, 112, without figure. The other *Favosites* of the Niagara formation is figured in Palæontology N. Y. Vol. II, Plates 34 A bis, and plate 73.

As the bed next below the Bastard Limestone, a buffish colored magnesian rock unfit for burning into lime 20′ thick, is full of marine shells without corals, it is fair to think that the *Cladopora bed* was deposited just at the eve of the invasion of the coral animals, who were already growing in many a distant locality and were gradually spreading their area of life towards Columbia county, the waves and currents sending before them their broken fragments as an announcement of their approach.

In fact *Stromatopora*, *Favosites helderbergiæ* and *Favosites spherica* grew in some places against and on top of one another; as is shown by the wonderfully fine Fig. 8, on plate VIII of Prof. James Hall's Fossil Corals and Bryozoans of the Lower Helderberg group, etc.* The section of a specimen shows *Stromatopora* growing on *F. sphærica;* this again on *Stromatopora;* this on *F. sphærica;* and this on *F. helderbergiæ.* (See plate CXXV B, p. 984.)

This figure will suffice of itself to enable the collector to distinguish the three on the surface of an exposure; and at the same time it demonstrates the fact that the *Stromatopora bed*, where solid, was originally a true sponge-coral reef in the bed of the sea.

After the *Stromatopora* had obtained foothold in Columbia county and the surrounding region, they grew like an archipelago of reefs, and were afterwards killed by some change in the depth or physical qualities of the sea water, or by some change in the ocean currents which brought all these deposits from some distant land, from the mouth of some great river. Whatever the exact nature of this change may have been,—whether a subsidence of the sea bottom, or a rise of the sea level, or merely a diversion of the currents of sea water to some new direction,—the *Stromatopora* growth perished (locally) and was covered up by marly, muddy and sandy deposits to various depths, up to 150′; ending with the great outspread of the Oriskany glass sand formation No. VII.

The depth of water in which this sponge-coral grew is

* Report of State Geologist of N. Y., for 1882, 4°, 1883.

wholly unknown. To call the *Stromatopora bed* a fossil *sponge-coral reef* may be correct so far as the assertion goes that the animals lived in masses where we find them fossilized, and that they were not broken up at distant places and deposited in a bed, in Columbia county, as other-beds above and below the *Stromatopora bed* evidently were. But the word *reef* may mislead us if we take it as an assertion that the *Stromatopora* grew at the surface of the water; for, they may have grown at the sea bottom even at great depths; in which case some malign quality must have been given to the sea water to put an end to their existence; or, which perhaps means the same thing, a change of sea currents began to overwhelm them with an intolerable load of mud and sand.†

The extent of the area occupied by this particular growth of sponge-coral can only be guessed at by the districts in which the outcrops of No. VI come to the surface holding the *Stromatopora bed.* Two outcrops run through Columbia, Montour and Northumberland counties, one on each side of Montour's ridge. Here the bed appears in Grove's, Low's & Russel's quarries; also in quarries on Limestone ridge a little further north. All beyond in that direction is covered up by higher formations far into the State of New York; but where No. VI comes up in Schoharie county west of Albany the *Stromatopora* occurs in it.

Eastward the formation lies deeply buried beneath the anthracite coal region and all northeastern Pennsylvania; but comes up to the surface, a hundred miles off, along the Delaware river in Pike and Monroe counties, bringing beds of *Stromatopora* with it.

† The evidence of dry land at this time in southern Schuylkill, northern Lebanon and Dauphin, and southern Perry counties, to the southward, in the Hudson river country to the east, and elsewhere (described on pages above), does not affect this question, unless it can be first shown whether the ocean bed was an even or an uneven plain; for, deep water may have existed a very few miles off shore from such dry land. In fact the great variations in thickness of the formations prove conclusively that the ocean bed was really uneven, and the water many hundred feet deeper in some places than in others.

No. VI stromatopora bed.

In Monroe county, in Middle Smithfield township, where the Delaware river cuts through No. VI above Decker's ferry, a great cliff of bluish-gray Stormville limestone 20′ or more thick overhangs the steep slope, and has dropped masses 10′ in diameter upon the river bank below, all smooth and rounded by the rushing waters and ice floes at high flood. In the cliff and in these fallen blocks are seen many fossil corals, *Stromatopora* and other allied forms, mixed with Lower Helderberg shells, *Pentamerus galeatus* etc. In Smithfield township, just opposite the middle of Dupuy's island, near M. P. Albert's house, the Stormville limestone makes a great cliff of 75′ vertical height, the base of which is 150′ above the river level. The lower beds of the cliff are largely composed of fossil corals, *Stromatopora* being especially abundant, some of the specimens being a foot in diameter. G 6, pp. 133, 219, 244.

In Columbia county at Mauser's quarry, Montour township, the *Stromatopora* masses from 2″ to 1½′ in diameter, stand out from the weathered cliff of Stormville limestone 12′ thick. At Creveling's quarry in Scott township the *Stromatopora* masses are less frequent. At Low's quarry in Centre township they are scarcely discernable. At Limeridge quarry near by they occur from 6″ to 1′ in diameter. At Evans' abandoned quarry in Briar creek township they appear in two forms as *S. concentrica* and *S. rugosa.*

In Montour county, at Grove Bros. tunnel in Cooper township, the Stormville limestone beds are 111′ thick and in the middle of them (160′ beneath the Oriskany) lies the *Stromatopora* reef bed, 10′ thick. At Appleman's quarry, half a mile further west, the *Stromatopora* bed is 15′ thick, some of the fossils being silicified. At Derr's quarry in Liberty township, it is 10′ thick, composed of vast numbers of *S. concentrica* and other corals. At A. F. Russell's quarry in Valley township it is 10′ thick, projecting from the top of the quarry in large masses, and composed wholly of *Stromatopora* and other coral *debris*, cemented into which are many broken up shells.

In northern Northumberland county, in Chillisquaque township, near Mrs. Younts', it is exposed in the road half a mile east of the quarry at the school house, a perfect mass of *S. concentrica* and other corals.

In southern Northumberland county near Selinsgrove RR. junction, on the north dip of the anticlinal, a *Stromatopora* bed 10′ thick lies 295′ below the Oriskany; and in this bed and an underlying 10′ limestone occur *Favosites helderbergiæ*, a *Zaphrentes*, with shells like *Strophomena rugosa*, *Atrypa reticularis*, *Spiriferas*, etc. This bed was not noticed on the south dip of the anticlinal, probably because the Stromatopores are hardly visible on freshly broken surfaces, whereas they stand out boldly to view on weathered surfaces. G 7, pp. 244, 257, 272, 299, 311, 334, &c.

In Perry county, I. C. White's *Stormville limestone* with its central *Stromatopora bed* is represented by E. W. Claypole's *Clark's mill lime shales*, 150′ thick, the top of which lies 100′ beneath the Oriskany No. VII, and in its middle appears the *Stromatopora bed;* thus:—F 2, 60.

ORISKANY SANDSTONE No. VII.

Flint gravel group.	White flint shales, ... 10′		
	Yellow flint shales. . . . 80′		. . . 98′
	Cherty black limestone, . . . 8′		
Clark's mill limeshales.	Tentaculite bed, ...		
	Polyzoon bed, . . .		
	Beyrichia granulata bed, . . .		
	Leptæna bed, ...		
	Stromatopora bed, ...		. . . . . 150′
	Sphyrocystites bed, ...		
	Rhynchonella bed, ...		
	Murchisonia bed.		
	Beyrichia notata bed, ...		
Lewistown limestone, massive, ...			. . . . . . 100′

In the typical Clark's Mill section so carefully worked out by Prof. Claypole, near New Bloomfield, the *Stromatopora* bed (with *Favosites*) 6′ thick, underlies the Yellow flint beds 98′. This makes it nearly 200′ beneath the Oriskany No. VII.—It is however not the only coral bed in the section; for 70′ above it is a bed of corals 6″ thick; and another 60′ above it, a solid mass of *Trematopora*. Under it 20′ is a 1′ shale full of *Syringopora* (?) and *Sphæ-*

rocystites multifasculatus; and another 1′, full of *Cladopora fibrosa* (?); while about 35′ below it is a rubbly 6′ with *Stromatopora* and *Favosites* (*Astrocerium*), overlying a 3′ shale with *Aulopora* (?) and *Sphærocystites.* F 2, 182.

In the Clark's mill section the *Stromatopora* masses are abundantly scattered through the bed of limestone, in company with *Favosites* or *Fenestella.* But in outcrops further south of Perry county the bed is a regular reef; as for example at Garber's quarry on Sherman's creek near Falling Spring, where the *Stromatopora* makes a solid bed, 5′ thick, 100′ beneath the Oriskany No. VII, composed almost wholly of silicified masses of the sponge-coral, with only a few interspersed nodules of *Favosites*, generally although not always calcareous, many of which can be developed by the use of acid. F 2, 338.

In Mifflin and Huntingdon counties the outcrops of No. VI, along the Juniata river and Aughwick creek valleys, from Lewistown to Orbisonia are abundant and fine, and exhibit remarkable variations of beds, thus: F, 162.

	Three Springs.	*Orbisonia.*	*Mt. Union.*	*McVeytown.*	*Lewistown.*
Oriskany,	58′	—	95′	140′	110′
Shale,	0′	195′	282′	65′	205′
Shale,	—	—	18	130′	140′
Shale,	162′	125	35′	215′	185′
Stromatopora beds at the bottom,					
Lewistown limestone,					

No distinct Stromatopora bed has been reported at any point along these outcrops; but in fact no proper field study of the fossils has been made. Collections, however, made at Three Springs in Huntingdon county show that at 112′ beneath the Oriskany No. VII 50′ of limestones and lime shales there beginning are full of coralline forms. *Acervularia, Alveolites minima, Astylospongia inornata, Aulopora, Conophyllum, Zaphrentis* and *Stromatopora*, mixed with shells.*

* F, p. 242. Whether the great enlargement of the deposits going east, produced by the thickening of the Lewistown limestone (from 162′ to 185′) and the coming in of two shale formations (140′+205=345′) between it and the Oriskany No. VII puts these corals at a depth of 400′ or 500′ beneath the Oriskany; or, whether the corals in the limestone in Huntingdon county are in the overlying shales in Mifflin county, must be studied out by a resurvey of the ground with such questions of palæontology in view.

At Mill creek on the Juniata in Brady township, at the Juniata Sand Co.'s quarries, the massive *Stromatopora bed*, 8′ thick, makes a cliff; lies 135′ beneath the Oriskany No. VII; the sponge coral protruding in vast numbers as irregularly weathered patches, in company with *Favosites helderbergiæ*, *Zaphrentis* and other corals. T 3, 269.

Along the Shy Beaver creek in Hopewell township the *Stromatopora bed*, 8′ thick, makes a cliff; 275′ beneath the Oriskany No. VII; has 75′ of impure limestone beds over it, the upper layers of which contain *Stromatopora* and *chert*. T 3, 163.

Near McConnellstown, Walker township, between 200′ and 300′ beneath the Oriskany No. VII are impure lime shales, etc. in which corals and crinoids (*Zaphrentis*, *Cladopora*, *Chætetes*, *etc.*) mostly in a broken up condition are plentiful. Large blocks of limestone, showing that solid beds occur in the interval, exhibit *Stromatopora concentrica* and *Favosites helderbergiæ*. T 3, 201.

Near the Bedford county line, at Powell's quarries near Cove Station, the *Stromatopora bed* is 3′ thick. Fifteen feet underneath it are 25′ of rather massive limestones filled with corals (*Stromatopora*, *Favosites*, *Zaphrentis*) and various shells; then 75′ limestones with flints, shells and crinoidal fragments. Then come the *good* or *quarry limestones* 90′; then poor limestones for 170′ more down to the Salina formation. The *Stromatopora bed* in this neighborhood. On Weaver's Run, Hopewell township, underlies the Oriskany No. VII by 240.′ It is entirely composed of *S. concentrica*. The 15′ limestone over it is largely made up of the broken and drifted fragments of crinoids, and is the purest rock of the entire series. This shows that the growth of the sponge coral was stopped by an inroading current bringing broken corals from some distance; but the current must have been of very pure water, not charged with river-mud. T 2, 123, 156, 159, 160.

In Bedford county, the *Stromatopora* bed has been traced by Prof. Stevenson to the Maryland line.—At Everett on the Juniata east of Bedford are 29′ of cherty limestones; under these, 18′ quarry limestone; then 6′ slaty limestone with *Stromatopora*; then the *Stromatopora bed proper*, 8′ thick, full of the sponge-coral in masses from 1″ to 1′ in diameter, giving to the whole rock a nodular appearance. Under it lie 3′ compact limestone; 6′ shaly limestone with some fossils; 7′ very siliceous limestone; finally underneath all bluish gray limestone, made nodular with *Stromatopora*, and containing other forms. T 2, 191.

In Monroe township, further south along this Black Valley outcrop of No. VI, at B. F. Mann's quarry, the limestone is rich in *Stromatopora concentrica*, *Favosites helderbergiæ*, *Streptelasma*, *Fenestella* and other bryozoans; with several genera of shells. T 2, 187.

At Bedford, under 100′ of limestone beds containing Crinoid stems and fragments, small shells and chert, lies 7′ of compact siliceous cherty limestone containing *Stromatopora, crinoid stems, Syringopora(?)* and *Zaphrentis*. About 40′ beneath this *Stromatopora bed* lies a remarkable *Leptoceelia imbricata bed*. T 2, 149.

On Wills creek, in Derry, at Devores quarry limestones underlie a *Stromatopora bed* (p. 97). At Hyndman, further south, 139′ of various shaly, flaggy and massive blue and gray limestones underlie the Oriskany No. VII. Under them lie 37′ of irregularly bedded blue limestone beds, making a plentiful exhibition of *Stromatopora* wherever their outcrops appear at the surface. Underneath lie 160′ of more flaggy and cherty gray and blue limestones. In some of the upper beds occur *Favosites*, *Caninia*, and brachiopods (*Orthis*, *Rhyn. vent.*, *Pent. gal.*) In the lower layers are seen the shells of the Delthyris Shaly Limestone group of Schoharie, N. Y. T 2, 87.

Along the Maryland line, on the Bean's Cove outcrops of VI, *Favosites*, *Caninia*, *Chætetes* and the accompanying shells, but no *Stromatopora* was noticed.— So also in the New Paris basin west of Bedford, *Favosites*, *Caninia*, and the usual shells but no *Stromatopora*. So also on the western outcrop of VI, along Dunning's mountain into Blair county *Favosites held. Caninia* and the shells, but no Stromatopora. T 2, 159; 121; 134.

In Blair county, near Allegheny furnace, 151′ of massive

(12″ to 18″) layers of limestone are seen under the Oriskany No. VII, almost every one of which is more or less fossiliferous; but no *Stromatopora* is mentioned in M. Platt's report. T, 129.

In Centre County, along the same outcrop at the foot of Bald Eagle Mountain, Prof. Ewing has collected *Corals* at Unionville, and *Trematospira? Zaphrentis* and *Corals* in curtains, but no *Stromatopora* are noted. T 4, 430.

In Lycoming county the outcrop of VI is mostly covered by the wash of the West Branch Susquehanna river; but where it rises to the surface and is quarried no fossils are mentioned in Mr. F. Platt's report. In Washington town it sweeps inland around White Deer Valley, and its lower beds are quarried in many places, but no fossils stated.

In Ohio the *Lower Helderberg* No. VI is only represented in its lowest member the Water-lime.* Consequently our *Stromatopora reef* did not stretch as far west as middle Ohio; but it may exist under western Pennsylvania, at a depth of—— feet more or less beneath Pittsburgh.—The *Oriskany No. VII*, also wanting in Ohio, being only represented by a thin layer (3′ to 10′) of saccaroidal sandstone.—Immediately upon it lies the *Corniferous limestone* (*Upper Helderberg*) *No. VIIIa*, in which four species of *Stromatopora* are found; 1. *S. concentrica* as in No. VI; 2. *S. ponderosa;* 3. *S. substriatella*; 4. *S. nodulata.*†

It thus appears that the sponges and corals, which at first made scattered and continuous reefs along a wide belt from Albany to Cumberland in Maryland, and so onward, were covered up and killed by lime muds and sands, and then reformed on a more extensive scale stretching far west. (See Fig. 3. Plate CXXV B.)

It is in the upper coral reef that the remarkable remains of huge armour-plated (ganoid) fish have been found in Ohio, so admirably described and figured by Dr. Newberry. They no doubt lived in the reefs and obtained their food by crushing the corals and sponges and sucking

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*Geol. Sur. Ohio Geol. Vol. 1, p. 63, 1873.

† All described by H. A. Nicholson, in Palæon. Ohio, Vol. 2, pp. 246–249, and 2, 3 and 4 figured in pl. 24.

soft tissues.—On these reefs, also, broken and macerated trunks of tree ferns were grounded, which had floated from some not far distant shore. The Corniferous is 100′ thick in Ohio, and 550′ in New Jersey,* and therefore represents a formidable amount of combined growth and float materials, and a considerable length of time. And yet it is not a continuous oceanic deposit; but represents a very irregular and shallow sea bottom. For although the Corniferous alone is 250′ at the east end of Monroe county, it thins away into Carbon county so as to entirely disappear on the Lehigh river,† and it is frequently absent in other parts of Pennsylvania. In fact it acts like the Oriskany No. VII, which is 200′ thick on the Lehigh, only 6′ thick in Columbia county,‡ 50′ and 100′ in other places, and for long distances in Lycoming, Clinton and Centre counties wholly wanting. The various groups of No. VI act in the same way; the *Stromatopora bed* being in one county 250′ and in another only 100′ beneath the Oriskany No. VII. §

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*Including the Candagalli grit; which however may be considered by some to be a part of the Oriskany.

† Where only the Candagalli beds remain, G6 p. 119, 121.

‡ G7, p. 227.

§ Two things are plain:—1, that however palæontologists may find it convenient to make up their vertical lists of genera and species and draw a line between Silurian and Devonian forms, there is no break in the continuous series of Palæozoic formations; but merely alternate contractions and enlargements of the great water basin in which they were deposited;—2, that every formation and part of formation was deposited in streaks and patches, representing water ways in a submarine archipelago, and extended over a great area only in that limited sense;—3, that the formations and parts of formations supplemented each other, so that where one was thin another would be thick, thus maintaining a general uniformity of total depth of deposit;—4, the maximum thickness of all was in the east, and the minimum in the west;—5, that for the same reason formations and parts of formations in Pennsylvania are wanting in Ohio;—6, that the general aspect is that of a vast river delta merging into an ocean bed deposit, the best representative of which in our day is afforded by the Amazon;—7, that the Amazon deposits however are not in all respects like these; because there is no coral reef in its estuary or off shore; and because its deposits, coming mainly from the Andes, have always been and are still a homogeneous and invariable mixture of all kinds of secondary rocks;—8, that consequently we must seek for an analogy also in the deposits and reefs of the gulf streams, the Bahamas, etc.;—9, that the source of the stuff and the geographical situation of the river or rivers must have been in part Canada, in part New England; but the coarser deposits and their maximum thickness

At Cayuga Lake N. Y. a *Stromatopora bed* lies just under the Oriskany, and another about 70′ lower; one of them is 4′ thick at two places half a mile apart.* The shale, limestone and gypsum interval contains nothing but L. Held. fossils.—At Skeneateles lake, *Stromatopora* is abundant in the 12′ limestone under No. VII.—At Oriskany Falls (18 m. S. W. of Utica) *Stromatopora* is rather abundant from 25′ to 54′ under VII, and over a 7′ bastard limestone; and again in the 45′ under the bastard (and this corresponds pretty well with our exposures in Pa.); also very abundant 110′–115′ below VII. †

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are referable to the Highlands, South Mountain and Blue Ridge range; and probably a back country of azoic rocks occupying at that time a large part of the present Atlantic ocean area, and connecting America with Europe;—10, that, judging by modern corals and sponges, the sea water must have been warm, sub-tropical, or tropical, and therefore flowing, as the gulf stream does, from the south;—11, that for the same reason, the land was to the southeast, and the expanse of ocean to the west, producing, as at the present day in Europe and California, an equable warm and moist climate;—12, that one river at least debouched in Pennsylvania through the break in the South Mountain range, which extends practically from Reading to beyond Harrisburg; and which not existing in Lower Silurian ages, probably did exist in Upper Silurian, Devonian and Carboniferous ages; although that is not certain.

Supposing the South mountain range in Pennsylvania and New Jersey to have existed in age No. VI, and supposing such a river to be flowing from the south into a sea which extended to Lake Superior, and supposing an equatorial current flowing northeastward along the shore belt of that sea turning westward through New York into upper Canada, it would not be impossible to explain the growth of sponge and coral reefs, and the alternations of fossil ore beds, lime marls, fossilferous limestones, sand banks, black muds, local Juniata coal beds, etc., which make up the succession of Upper Silurian and Devonian formations Nos. V, VI, VII and VIII.

*S. G. Williams, Am. J. S. Art. XIV, p. 140.

† Bigsby's tables (Thesaurus Devonicus, 1878, p. 7) give the following species and their ages, as there known:—In *Lower Silurian, Stromatopora striatella, canadensis, rugosa, compactus*, and an undetermined species by Hitchcock, to which must be added *Stromatocerium rugosum*, Hall, and S—? Salter from Tasmania.—In *Upper Silurian, S. concentrica, constellata, striatella, nummulisimilis* in the English Wenlock.—In *Lower Devonian, S. capitata, concentrica, erratica, ramosa.*—In *Middle Devonian, S. concentrica, exspitosa, monticulifera, nux, pustulifera, placenta, ramosa, verticillata*, and another unnamed in Illinois.—In *Upper Devonian, S. concentrica, patella, placenta, polymorpha, stellifera, ramosa.*

In 1886, Dr. C. Rominger read before the Acad. N. S. Philadelphia a paper on the structure of *Stromatopora*, and its allies.

In 1887, Prof. J. F. James read a paper before the Cin. So. Nat. Hist, on

Protozoa of the Cincinnati group (III), in which he says on account of the jelly-like nature of the animals they were difficult of preservation and can only be studied by microscopic sections. Only two orders have been found fossil in Ohio: the *Foraminiferæ*, and *Spongidæ*. He considers Billings' *Beatricea* (sp. *nodulosa* and *undulata*, perhaps the same) the only foramifer as yet found in the Cincinnati rocks, although *Receptaculites* and *Stromatopora* "have been referred here"; originally described as a plant; then as a coral; by Hyatt in 1865 as a mollusk allied to the Cephalopods, and in 1884, as one of the foramenifera.—The Cincinnati sponges he describes as *Astylospongia gregaria*, and *tumida*; *Pattersonia difficilis*; *Brachiospongia digitata*, and *tuberculata*; *Pasceolus globosus* and *darwinii*; *Ischadites* (*Lepidolites*) *dickhauti* (*elongatus*); *Receptaculites* (*Anomaloides*) *reticulatus*; *Stromatopora* (*Dystactospongia*) *insolens* (massive), *tubularis-subcylindrica* (Ulrich's *Labechia montifera*), *lichenoides*, *scabra*, *papillata* and *ludlowensis*; *Stromatocerium canadense* and *richmondense*.

CHAPTER LXXV.

No. VII, Oriskany Shale and Sandstone, and Cauda-galli Grit.

The Oriskany* sandstone is in one important respect a repetition of the Potsdam (No. I.) sandstone deposit.† Its constitutent grains are sharp quartz fragments so loosely cemented as to fall apart under the action of the air into heaps of glass sand; and the standing rock of the outcrop can be readily crushed by machinery into the same condition. Even where the rock is blasted the blown off fragments break to fine sand which need only to be washed to be prepared for the market.

Glass factories have hitherto relied upon this Oriskany formation No. VII for the principal part of their stock. It is extensively quarried on both sides of the Juniata river at Mapleton below Huntingdon, and regularly mined on the north side of the river at McVeytown in Mifflin township, for consumption in Pittsburgh. It might be exploited for glass sand in many other places in middle Pennsylvania, but the consumption of the material is of course limited; and these quarries are so well placed in relation to the great line of railway transportation, and furnish the

**Oriskany* should be spelled *Areskana*, for that was the Indian name, meaning *Champs de Mars*, or residence of the God of War; the council-fire of the Aganousioni, or United Braves. (G. F. Yates, in Hall, 1843, p. 146.)

†Vanuxem long ago remarked that No. I and No. VII were the only palæozoic formations which seem to have been directly derived from the Azoic mother rock. The following analysis (a) by Mr. A. A. Blair, first published by A. F. Brainerd in a paper before the Am. Inst. Mining Engineers, Feb. 1886, of sand mined by A. O. Brainerd, near Mooer's Fork, Clinton co. N. Y. over an outcrop of Potsdam Sandstone No I, curiously resembles A. S. McCreath's analysis of No. VII sand in the Lewistown valley, Mifflin co. Pa. (b) given further on; and an analysis of azoic sand from Berkshire, Mass. (c):—Silica, 98.88 (b, 98.84, c, 98.77); alumina, 0 59 (b, 0.17, c, 0.67); peroxide iron, 0.14 (b, 0.34, c, 0.25); lime, a trace, (b, trace, c. none); magnesia, 0.05 (b, trace, c, 0.06).

stuff in such quantities as to discourage enterprise elsewhere.

In New York State the northern outcrop is single, and stretches east and west along the Mohawk valley, turning south down the Hudson valley for many miles.*

* The Oriskany sandstone in eastern New York is not noticable along its southern outcrop, between the Delaware river and the Hudson. It is first seen at Esopus Falls near Kingston; but can be then followed by occasional outcrops up the west bank of the Hudson, along the foot of the Catskill mountains and along the front or northern bluff of the Helderberg, facing the Mohawk valley; seldom exceeding 2′ in thickness; in many places less than 1′; and in some places entirely absent; but always strongly marked by its large fossil shells, which readily attract the attention of travellers. These fossils are crystalline carbonate of lime, which at the surface are dissolved out, leaving nothing but the moulds of the fossils in the rock. The rock itself is generally a hard silicious grit, almost like chert, flint, hornstone in some places white, in others brown, red and black, sometimes slightly calcareous. (See Mather's report of 1843, pp. 342; where woodcuts of *Delthyris arenaria*, *Atrypa elongata*, *Atrypa peculiaris*, *Hipparionyx proximus*, and *Delthyris arenaria*, are given. The same fossils are shown in Vanuxem's report, pp. 123-124, from the same woodcuts.)—Its outcrop along the Mohawk valley projects from the face of the Helderberg mountain, forming a terrace resting upon the Shaly Limestone (called 40 years ago, *Catskill shaly limestone*); and passing under the bluff of massive thick *Caudagalli grit*. It is best seen near Salem, but it takes its name from its outcrop at Oriskany Falls a few miles west of Utica where it is a pure, light yellow sandstone. At other places the yellow color is often shaded brown or is dark. Generally it consists of medium sized quartz sand, such as would be produced by the rubbing down of granite, gneiss or mica schist; but the general smallness of the grains shows that they have come from Azoic land at a considerable distance, probably the mountains to the north or to the east. The formation is everywhere thin and exceedingly irregular in thickness, as at Manlius south of Oneida lake, where only a few few inches of Oriskany sandstone separates the Water Lime under it from the overlying Corniferous; and at Perryville Falls and below Casanovia where it is only a few inches thick. At Oriskany Falls is the best exposure of it in the State, it being, like the limestone under it, uncovered for some distance along the canal, in the hillside. It consists of three distinct massive strata. It contains curious sandstone nodules or black pebbles in some places, some of which have been afterwards removed, water-worn and then re-deposited in the lower layers of the overlying Onondaga limestone (Vanuxem, 137). It contains at one locality (Perryville), a large amount of red oxide of iron in the lower layers, but too much mixed with sand to be smelted. Elsewhere the iron in the formation is so distributed as merely to darken or blacken it.—Between Skeneateles and Elbridge the formation shows a thickness of 30′; its middle layers being penetrated vertically by worm burrows (*Scolithus linearis?* originally looked upon as a *Fucoid*), the sandstone being white yellowish and dark gray, with iron spots. A well near the outlet of Lake Skaneateles went 22′ feet through sandstone

In Pennsylvania the outcrops of Oriskany extend in straight and curved lines and many zigzags through nineteen counties, a total distance of 1100 miles; the formation

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to the limestone; but north of Auburn the whole formation varies from $2\frac{1}{2}$ to a few inches.

The Oriskany in New York is a pure whitish coarse sand, loosely cemented; contains flattened nodules of flint; also cavities lined with flint (chalcedony); also, in its upper part balls of black quartzite (1″ to 5″ in diameter) hard tough looking boulders of some primary rock.

At Vienna (80 miles N. N. W. of Seneca lake) it is only 4′ thick, holding concretions, and lying between *Onondaga* limestone above and *Waterlime* below, all the intermediate formations in eastern New York having thinned away. Thirty miles further west (West Mendon, 15 miles south of Rochester) it has thinned to only *four inches* of coarse, greenish, *conglomeritic sandstone;* between *Onondaga limestone with coral* above, and *Salina Cement beds* below (See Hall's sections, p. 139); but it appears at one or two places further west, the last being in the bed of Black creek at Morgantown in Genesee county.

This conglomerate is a bed of coarse sand and small pebbles, *with some fragments from the underlying limestone beds,* which are assumed to be good evidence, not only of the emergence and erosion of the older formation, but that sufficient time had elapsed for the older limestone beds to become consolidated, broken, worn into pebbles and redeposited. That a good of time elapsed between the Salina salt beds and the Oriskany sand deposits is certain, for hundreds of feet of limestone and lime shales of No. VI, with coral reefs, in Pennsylvania, are entirely wanting in Western New York. But the evidences of erosion are also wanting; and the consolidation of lime mud into limestone, and of sand into sandrock does not take place in the air, at the eroded surface, but before emergency and *under great pressure.* These supposed Salina fragments in Oriskany sand must therefore have come from a great distance, and been deposited here on Salina beds which had never emerged. We know of no agent of transportation applicable to this case except a tidal current along soundings, rolling small pebbles along a coast, and enveloping them in river sand from an azoic country. But the extreme purity or Oriskany sand is hardly compatible with the supposition of its being ordinary river sand. Could we postulate a catastrophy, sudden and short, a rush of great quantities of water over the disintegrated surface of some not too distant continental area of quartzite mountain land, transporting into the sea its sweepings which settled far out from shore in water not too deep for large shells to live in, we would still encounter insuperable objections; especially from the necessary yet unnatural slowness of such settling. The fact is, no explanation of the Oriskany formation is yet at our command; and it will probably continue to be one of the phenomena of nature most irritating to the curiosity of the geologist.

An evidence of erosion is found by Prof. Hall in the fact that between Rochester and Buffalo, where *Oriskany* is absent, the underlying *Salina* surface is uneven, with abrupt ridges and hollows, as if channeled by water courses; but "no grooves or striæ observed," although they may exist. But the admirable judgment of the distinguished observer keeps in view the however appearing and disappearing, thickening and thinning; varying in character from sandy shale to massive flint rock; in some places crowded with shells, at others almost destitute of them; in some places calcareous, in others with scarcely a trace of lime; in some places highly ferruginous, even containing iron enough to furnish furnace ore.*

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alternative which our young geologists are apt to forget or ignore, when he says that if the formations of Eastern New York lying between the *Water-lime* and *Oriskany* were never deposited in Western New York, the *Water-lime* (and more extensively the salt group) must have remained exposed above the surface ot the ocean, *or* must have formed the ocean bed *in situations beyond the reach of any detritus or deposition.* On the other hand the four missing formations have distinct fossils faunæ, and must have four ages of sediment, during which ages it seems incredible that the Salina sea bottom however deep or distant from land should not have received some kind of covering however deep or distant from land. But, in fact, the distance from eastern to western New York, from where the four formations are thickest to where they disappear is only 250 miles. (Hall, p. 146–7.)

Another evidence of emergence is found in the shrinkage cracks of the Upper Salt groups; but these are more numerous in eastern New York where the formation is covered by the other formations, than in western New York where it is not. So that, as Prof. Hall shrewdly remarks, if shrinkage cracks be insisted on as proof of emergence we must conclude that the eastern Salt group land became submerged to receive the four covering formations while it remained exposed to the air in western New York. (Hall, 147.) But shrinkage cracks may be produced in several ways; and those which we see in modern tidal estuaries do not prove land elevation, but continuous land depression.

It is evident that the missing formations disappear westward not by erosion but by gradually thinning, that is, from lack of material carried out to sea; for they are wanting in all the Western States; and, had they existed over so vast an area their subsequent erosion would have left innumerable and irregular marks. (Hall, 147.)

These considerations should be well weighed by those who accept the asserted shore-erosion around the Cincinnati anticlinal; the asserted nonconformability of *Oneida and Hudson river* (IV on III) at the Lehigh water gap; and many other debatable explanations in local geology.

*Prof. Hall draws attention to the influence of fossils over the character of the rock. Where the sand formed and no shells grew in it it has in course of ages been cousolidated into hard compact fire-stone, approved for use as a hearth stone for blast furnaces. Where shells grew in abundance in the sand they have been dissolved out by percolating rain water, leaving the rock porous and honeycombed. In many districts it is so charged with carbonate of lime as to be in fact a sandy limestone, as along the Helderberg mountain in eastern New York, or the Delaware, and on the Upper Juniata waters in Pennsylvania. (Hall, 1843, p. 146.)

No. VII. The Pennsylvania outcrops.

The southernmost outcrop line crosses the Delaware river from New Jersey at Walpack bend in *Monroe* county and makes the steep rocky (Godfrey's) ridge running along back of the Blue mountain for 33 miles ; continued as the Steinberg ridge 17 miles through *Carbon* county ; and 15 miles further in *Schuylkill* county. Here the formation has thinned away, and the outcrop is scarcely visible the remaining 25 miles in *Schuylkill*, 12 in *Lebanon*, and 15 in *Dauphin* counties.

On the Susquehanna river the outcrop is wanting ; but it reappears in *Perry* about 10 miles west of the river.* Its zigzags through Perry county measure in all about 140 miles. In *Juniata* county there is a long sweep of 40 miles ; 20 miles in *Huntingdon* county ; and 5 miles in *Fulton* county, where it is swallowed up by Dr. Henderson's fault for 25 miles and reappears near the Maryland state line, across which it keeps on south. *Total length 360 miles.*

The long, narrow anticlinal of Shade and Blacklog mountains is surrounded by a continuous outcrop in the shape of an Oriskany ellipse, about 125 miles long, the eastern point of which is in Northumberland, and the southwestern point in Fulton. Measured along its zigzags there are of this outcrop 5 miles in *Northumberland*, 45 in *Snyder*,

*The lack of VI and VII and a part of VIII along the Blue mountain outcrop, from Schuylkill to Perry county, may result from one of three causes : 1, a fault along the great overthrow, swallowing up their outcrops ;—2, a failure of the deposits; dry land, etc.; or 3, a deep sea scour, either (*a*) preventing their settlement, or (*b*), removing them after they had been deposited. The last suggested cause is not a very likely one, but it is not by any means absurd after what has been reported by deep sea sounding. Submarine currents strong enough to produce deep sea erosion have been generally discarded as old fables by geologists. But they have lately revenged themselves in a most unexpected manner. The Falmouth cable at its depth of 3000′ (500 fathoms approaching Gibraltar was ground like the edge of a razor ; and (says Sir James Anderson) "we had to abandon it and lay a new cable well in shore." He quotes Captain Nares of the Nemesis surveying expedition, as getting no specimen whatever from the bottom on account of a "perfect swirl" of water at that depth. T. Mellard Reade's North Atlantic as a Geological Basin. Pres. Add. to the Liverpool G. S. session, 1885–6, p. 17.

about 55 in *Juniata*, 40 in *Mifflin*, 45 in *Huntingdon*, and 10 in *Fulton*. *Total length 200 miles.*

A far more extensively continuous outcrop surrounds the great anticlinal region of Kishicoquillis, Penn's, Brush, Nittany, Sinking Spring, Canoe, and Morrison's Cove valleys, continued into Maryland. This outcrop surrounds Montour's ridge and points out east beyond Bloomsburg, Columbia county ; surrounds Bald Eagle mountain and points out eastward near Muncy, Lycoming county ; surrounds Jack's mountain, and zigzags through Huntingdon county, making Warrior's ridge, and the pulpit rocks; runs south at the east base of Tussey mountain into Maryland ; and in like manner follows the west base of Bald Eagle, Dunning's and Will's mountain their whole length into Maryland. Thus there are 35 miles of it in *Columbia* county ; 12 in *Montour ;* 52 in *Northumberland ;* 32 in *Snyder* ; 10 in *Union* ; at least 50 (duplicated and zigzaged) in *Mifflin ;* 90 in *Huntingdon ;* 125 in *Bedford;* 65 in *Blair* ; 36 (interrupted by thinning away of the formation) in *Centre ;* and 35 (similarly interrupted) in *Lycoming. Total length 542 miles.—Grand total*, *say*, *1100 miles.*

No. VII, as a supposed division between the Silurian and Devonian systems.

Although the Oriskany sandstone has been adopted as the plane of sub-division between the Silurian system below, and Devonian system above, and although the general aspect of the rocks and of their animal fossils suffers a visible change of great importance both to the practical miner and to the scientific naturalist, nevertheless that change is by no means great enough to lead us to suppose any very great change in the order of the world like the commencement of a new book in geological history. The general arrangement of land and sea abode the same. No cataclysm took place, so far as we can see. The Silurian sediments were not generally lifted into the air, dried, worn away by the weather, again covered with water, and the Devonian sediments deposited upon their upturned edges. Nothing of that kind took place. The sea remained where it was, even if its general level was somewhat lowered, altering in places the shape of its far-off shores, the direction of its currents, and therefore the character of the sediments which continued to come into it.

There is no non-conformity of stratification, except what was caused by the appearance at sea level, in various places, of sand banks connected with previously living coral reefs, and soon submerged again to form the resting places of other and younger coral reefs. The Devonian strata are all practically conformable with the Silurian, and were laid down upon them in the quietness of an uninterrupted or but slightly modified state of things. The same great rivers entered the ocean as before, and their sands and muds moved forward under the impetus of similar currents turned hither and thither by slight variations in its shallow bed. The fossil ore beds of the Clinton (No. V) repeated themselves in the Hamilton (No. VIII); the white gravel beds of the Oneida (No. IV) in those of the Middle Hamilton; and the red shales and sandstones of the Medina and Clinton (IV and V), in those of the Upper Chemung and Catskill (VIII and IX.)

The Caudagalli and Schoharie grits.

The *Caudagalli grit* and *Schoharie grit* are evidently the upper parts of the Oriskany sandstone, and should be included in No. VII. And it is an open question whether No. VII should not include also the Onondaga and Corniferous; thus allowing No. VIII to begin with the Marcellus shale.*

The *Caudagalli grit* is almost a non-fossiliferous rock, both in New York where it is well developed, and in Pennsylvania where it is sometimes very indistinctly exhibited. Prof. Hall says in the fourth volume of his Palæontology that a few fragments of plant-like fossils (those peculiar

*The *Upper Helderberg group* in New York was made originally to include the Oriskany sandstone and the overlying Cauda-galli grit, Schoharie grit, Onondaga limestone and Corniferous limestone, up to the base of the Marcellus shale of the Hamilton group.

cocktail surface-markings on the slaty laminæ from which the name is derived) are the only objects resembling organic bodies in it. Up to 1867 only one specimen of a *Platyceras* (like *P. tortuosum* of the Oriskany) had been found in it. The passage from Oriskany to Cáudigalli is in New York very abrupt and strongly defined. The so called grit is usually a sandy shale, dark or nearly black, weathering to grayish or brownish gray; with strong lines of jointing nearly at right angles to the bedding. These, being often close together and well defined, while the lines of bedding are obscure, give it (where lying flat) the false appearance of nearly vertical stratification; and that at a great distance from any metamorphic country. "These features distinguish the rock from any other in the series; and even in its smaller outcrops the vertical lamination has been found a valuable guide in its identification." (Hall, Pal. Vol. IV, pp. 2.) In the upper part, we find a gradual increase of calcareous matter, with a diminution of clay; and it passes by almost imperceptible gradations upward into the Schoharie grit, which is marked by numerous fossils. Both the upper Caudagalli beds and lower Schoharie beds are marked by the cocktail fucoid.

From the base of the Schoharie grit upward, a few species of shells make their first appearance, which continued to live through the overlying Corniferous limestone time, and became more abundant in the Hamilton age, namely; *Orthis vanuxemi*, *Streptorhynchus chemungense*, *Strophomena demissa*, *Strophomena perplana* (*crenistria*), *Spirifera fimbriata* (two individuals of which species had been found up to that date in New York in the Oriskany), and *Atrypa impressa* (a variety of *A. reticularis ?*).

Besides these species, which may equally well be called *Hamilton forms*, there are a large number of species common to the grits and overlying limestones which do *not* become Hamilton fossils.

On the other hand, a few species occur in the grit which seem to be identical with those which lived in underlying formations; but their number is so few, and their individuals comparatively speaking so rare, that the large number of

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new species (of the same genera) makes them inconspicuous. We may therefore speak of the introduction of a new fauna; the most marked features of the change being thus described by Professor Hall:—

The genera of *Cephalopods* (*Cyrtoceras*, *Gyroceras*, *etc.*) present now for the first time, numerous species with strongly lamellose, fluted surfaces, often ornamented with nodes or spines. Some of the *Orthoceras* species are marked by sharp lamellose rings. Some of the *Gasteropods* bore spines. The *trilobites*, *Dulmania* and *Phacops* are remarkable for their spiny character; and the *trilobites*, *Lichas* and *Acidaspis* (fragments) have extravagent forms.

All this impresses the palæontologist with the feeling that, if the Silurian world of life was followed by a different Devonian world of life by any radical change in the general state of things, that change probably took place not at the bottom of the Oriskany, but at the top of the Caudagalli grit; which makes it all the more natural to consider the Caudagalli as the upper member of No. VII. Many of the new types are of a strikingly distinct character, and pass up into the Hamilton; just as many species which first appeared in No. VI passed up into the Oriskany.

The Caudagalli outcrop in many places along its outcrop in eastern New York has a thickness of 50′ or 60′ (Mather's Report on First Dist., pp. 341). It can be followed along the face of the Helderberg mountains through Schoharie county, and the foot of the Catskills, southeast and south to Kensington on the Hudson, but was not recognized in the Memakating valley further southwest than Marbleton. The cock-tail* impressions are very abundant in many places along this extended outcrop. The rock is a lime clay grit, almost as fine-grained as slate, and crumbling under the weather; in some places almost black; more frequently gray or buff, weathering still lighter.

The Caudagalli outcrop, running west from Cherry valley along the face of the Helderberg, appears on the Fort Plain road, and the Judd's furnace road, and in the brook

*For two good illustrations of the fossil see Mather, pp. 341, and the same in Vanuxem, pp. 128.

between the two where its fracture is finely granular, the rock slightly calcareous, with sufficient iron to turn red when burned; often solid enough to make a good fire-stone.

In the Fort Plain-Cooperstown road quarries its drab colored slabs contain green grains like those at Canajoharie. Vanuxem says that the outcrop can be followed west through Madison county, until it feathers out before reaching the western line. Its disappearance then lets the Corniferous limestone down upon the Oriskany sandstone. This is an important feature of its New York outcrop, because in harmony with its disappearance in so many districts of Pennsylvania. But it is a mistake to suppose that the formation had a definate local area; for it appears at the surface at very distant localities; in the Mohawk valley, on the Delaware river at the north point of New Jersey, and on the upper Juniata river in Pennsylvania, where I have seen a block weighing several tons crowded with the cock-tail fucoid. The distance across from the Mohawk outcrop to the Delaware river outcrop, and the Lehigh Water Gap, exceeds 100 miles; under the whole intermediate region the formation may or may not exist continuously; of that we can have no knowledge.

The beautiful cock-tail fossil, supposed to have been a sea-weed, assumes many varieties of form, the two most characteristic being those shown in the wood cuts, the spiral, and the rooster's tail, both consisting of a multitude of long thin feathers rooted to a small stem, the feathers growing in a flat plane, but curved upward from the stem, and then downward to the margin, so that the upper side of the fossil preserved in one specimen appears rounded, while the under side preserved in another specimen will appear hollow. The curves of the feathers, although seeming to be continuous, are usually interrupted or broken. The breadth of the *spiral form* varies from 4″ to 12″; is more or less circular; and has no well defined outline, fading away insensibly into the stone. The *cock-tail form* on the contrary has a well defined outline, as if the feathers along the edge were glued together. This form is rarer than the other Caudagalli in the grit, but becomes more common in the overlying rocks. Some of these fossils are quite black, as if painted with a material like that which coats the fossil specimens of *Cypricardites* in the sandstone quarries south of Rome; and, as Vanuxem remarks, this suggests a space between the fossil and its matrix. He remarks also that the feathery forms are generally arranged in parallel planes; and that, on account of their broad surfaces and loose attachment, the rock readily breaks in the planes of the fucoids, and therefore very irregularly. Professor Rogers (in his New Jersey report) describes the fossil "as a circular disk (often a foot in diameter) of radiating arched fibers curving outwards from the center always in the same direction (spirally), like the hair parting on the crown of a man's head." There can be no doubt that it was a sea plant showing great variety in its mode of growth. In the age which followed the Oriskany, it assumed the beautiful curtain like form, which is not uncommon in the Hamilton rocks. (See wood cut in Vanuxem. pp. 1601.) See reduced figure on pl. CLXI below.

The *Schoharie grit* in which new species make their appearance in such abundance, as mentioned above (and which therefore palæontologically belongs not to No. VII, but to the limestone at the base of VIII) is a much more local and insignificent deposit than the Caudagalli grit. In its outcrop of the Mohawk Valley it is only seen in the neighborhood of Schoharie and of Clarksville in Albany county;* as a fine grained, very fossiliferous calcareous grit, the carbonate of lime weathering out and leaving it a porous spongy fine grained tough sandstone. The casts of straight shell *Cephalopods*, and of the *Pleurorhynchus* are abundant and serve to make the rock recognizable.†

*Fragments of a similar rock however were observed by Mather in many other places in eastern New York, but nowhere in place.

† Its numerous species will be described at the beginning of the chapters on No. VIII. A calcareous fine grained sandstone has been found in Indiana which weathers out its fossils in the same manner, and they are of the same species; those of the genus *Pleurorhynchus* being as abundant there as in New York.

CHAPTER LXXVI.

No VII on the Delaware and Lehigh rivers.

Along the New Jersey shore of the Delaware river from the bend at Carpenter's Point or Port Jervis runs a bold ridge faced on the river rise and crested by outcrops of *Caudagalli grit* dipping northwest; underlaid on the southern slope by *Oriskany shales without sandstone beds.*

The *Caudagalli* formation is a series of extremely hard, coarse, dark gray or dirty ash colored sandstone flags, cleft into rough slabs by joints dipping steeply southeast; resisting the weather; presenting acres of bare rocks, as on the river bank a mile below Carpenter's Point, where the dip is 25° (N. 20° W.) and the thickness of the group 315'. Its strata become less coarse westward. On Broadhead's creek, opposite the Delaware Water Gap, they stand vertical and measure only 250'. Still further west, in Hamilton township, Monroe county, the formation thins away rapidly; and in Carbon county it can hardly be detected at all.

No building stone can be got from these strata; but they weather sometimes into "slate-gravel," or long chips, excellent road-metal.

The characteristic *cock-tail seaweed* (*Fucoides caudagalli*) is seldom seen in them, and fossil shells are not abundant, are badly preserved, and distorted by pressure. *Strophomena rhomboidalis* and *Atrypa reticularis* are however rather common.

The *Oriskany formation* changes its character in so remarkable a manner along the line of its outcrop which extends 60 miles from Carpenter's Point to the Lehigh water gap, as greatly to embarrass the systematic geologist how to define or describe it, either as a single or a double formation, and whether to include its lower division (where it is double) in No. VI, or in No. VII. This embarrassment in fact is encountered in all parts of middle Pennsylvania where the formation comes to the present surface; and perhaps would meet us if we could follow it underground beneath the regions where it exists at variable depths,* for what we know of it along its narrow lines of outcrop is as nothing in comparison with what our knowledge of it would become could we uncover it for examination everywhere; yet even then we should remain in ignorance of its origin and of its character over a still greater expanse from which it has been swept away forever. In this, as in so many other cases, the famished geologist is seated at a Barmecide feast; or like Sebastian in Prospero's island sees harpies snatch away the tempting dishes from a loaded table; or like a poor retainer cheated with ever unfulfilled promises of preferment; or the lover whose longings slowly perish under the unconquerable indifference of Nature to his fondest protestations.

At the east end of the line, at Carpenter's Point, the *Oriskany proper* is a lime-shale deposit, 50′ thick *without a single layer of sandstone;* is studded with chert; and weathered down into muddy looking beds holding *Oriskany fossils:—Tentaculites elongatus*, *Platyceras gebhardii*, *Platyceras ventricosum*,† *Pterinea textilis* (*arenarea*), *Rensselaeria ovoides*,† *Eatonia peculiaris*, *Spirifera arrecta*, *Spirifera arenosa*,† *Meristella* ———? *Discina juvenis*;‡ beneath which lie 150′ of lime-sand-shales, fossiliferous at top, and at several horizons between the top and bottom, called by Prof. White *Stormville shales*. The whole 200′ fall naturally into one group of lime-shales; beneath which lie the solid, massive, cherty, siliceous and very fossiliferous *Pentamerus limestone* and *Stromatopora*

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* Beneath Pike, Wayne and Susquehanna counties the Oriskany lies at depths of 6000′, 7000′, and 8000′, slowly rising to the surface in the Helderberg mountain side facing the Mohawk valley in New York. In Carbon county it plunges at once to a depth of 5000′ in the first two miles (at Perryville), and to a depth of 13,000′ at Mauch Chunk.

† Found also on Broadhead's creek by Prof. White, and with them *Orthis hipparionyx*.

‡ Described by Dr. Barrett of Port Jervis, in the Annals of the N. Y. Acad. of S. Vol. 1, No. 4.

coral limestone beds of the Lower Helderberg formation No. VI.

At the west end of the line, at the Lehigh Water Gap, both the *Oriskany proper* and the *Stormville* (*Oriskany*) shale formation under it, are so sandy and have so little lime that they may be taken together as one *Sandstone formation*, the upper division of which is massive, and the lower division for the most part shaly, but at the bottom of it a very massive (Stormville) conglomerate.

We can first detect the change in the character of the whole formation where it enters Pennsylvania at Walpack bend of the Delaware river. Here directly beneath the *Caudagalli grits* appears a thin cherty conglomerate sandstone (8′ to 10′), which when followed along the river bluffs grows thicker, coarser and more massive; 45′ opposite the Delaware Water Gap; 175′ at the Monroe-Carbon county line; 200′ opposite the Lehigh Water Gap.

Beneath the Sandstone at Walpack Bend the Carpenter's Point lime shales are 150′ feet thick, holding *Spirifera macropleura* and other Lower Helderberg fossils; and at bottom appears a calcareous conglomerate (10′ to 15′).

This *Stormville conglomerate*, opposite the Delaware Water Gap, lies directly on the top limestone of No. VI, in which *no pebbles* are seen. At Stormville (5 miles further west) it is 25′ thick and lies on 20′ to 25′ of *limestone holding many quartz pebbles*. In Ross township (further west) the whole intervening mass of lime shales (between the upper and lower conglomerates) have become light gray and sandy. On the Lehigh the change is complete from lime shales to sand shales.*

*How this change has been brought about, or to speak more properly, what was the reason that the deposits of Lower Helderberg age (No. VI) continued to be limy and not sandy over the ancient sea bottom (now Pike and eastern Monroe) but were succeeded by sandy and not limy deposits over the same sea bottom, of the same age, at the same time (where now is western Monroe and Carbon counties) it is impossible even to conjecture with any approach to the probable truth. We shall see that there is the same difference between the Perry county and Mifflin county areas in Middle Pennsylvania.

The Oriskany (Stormville) shales.

In the chapters on No. VI, the *Stormville shales* have been described; and in middle Pennsylvania, in Perry county, the equivalent *Clark's Mill shales.* But on the Middle Juniata where they are called the *Oriskany shales*, they are included in Formation No. VII. The relationship of these shales (*Oriskany sandstone*) to the *Stormville (Oriskany) lime shales* beneath them has been shown in the "Nearpass quarry section" on page 919 above. But this interesting formation will now be described in much greater detail then the others because of the classical importance hitherto attributed to it as the supposed horizon of separation between Silurian and Devonian ages of Palæozoic time; a distinction which is destined sooner or later to be ignored by future geologists; or at least to lose most of its value as an epochal index of vital change in the condition of the physical world. The time will probably come when a better if not a crucial horizon will be fixed at the base of the *Marcellus*, and when Upper, Middle and Lower Helderberg will be regarded together as but one sub-division of the Palæozoic column. The present pre-eminence which the Oriskany sandstone No. VII enjoys as a strong line drawn across the column will then be lost, and it will fall back into the crowd of those strange sheets of sand which coming from no one knows where, and arranged by currents no one knows what, belong to every age of the world's history.

The outcrop of No. VII enters Pennsylvania at the southeast corner of Monroe county, at the Walpack Bend of the Delaware river; a picturesque spot where the broad stream turns back upon its course, flows along the north face of a hogback of sandstone (See fig. on p. 1050, pl. CXXXI) about 600′ high;* and, having cut through it, doubles again as suddenly and resumed its southwest course along the foot of the Shawangunk mountain.† The side

*The road leading from Bushkill to Decker's Ferry crosses the crest of the ridge at a height of 600 or 700′ above the river.

† The course of the Delaware along the southern line of Pike county is S. 65° W. 26 miles. At the mouth of Bushkill creek it flows S. 50 rods; then

slopes of the ridge are excessively steep, and its crest is only a few feet wide. A section through it, crossing the river three times shows how the ridge is constituted; the crest being an outcrop of the hard, dirty gray, slaty, fine-grained layers of *Caudagalli grit*, dipping 40° (N. W.), but traversed with so many nearly vertical (S. dipping) *cleavage planes* * as to deceive the observer, thickness say 300′; no fossils seen except impressions of *Spirophyton* (*Taonurus*) *caudagalli*; the surfaces covered with glacial scratches (S. 45° W.).†

At Walpack bend the *Oriskany* formation crosses the river about half a mile above Decker's Ferry, its outcrop being concealed in the steep hill slope. Two miles west (opposite Van Campen's island) it runs through the field just north of the crest of the ridge, showing very few pebbles. Two miles further west (M. H. Dimmick's) the *Stormville shales* make the crest, and the *Oriskany* shows as a massive conglomerate ledge, 15′ high, dipping 25° (N. W.) under *Caudagalli* beds. At the township line (J. Hanna's) it makes a cliff of 15′ to 20′, pebbly and fossiliferous, 950′ A. T., i. e. 635′ above the river. On Shawnee creek (J. Mosier's) an anticlinal roll spreads out its top layers horizontally, and two lines of cliff-outcrop may be followed by the eye for miles up both sides of the valley, until near its eastern head the *Oriskany* is covered by a broad expanse of *Caudagalli* strata.‡

Shawnee creek in fact, splits the Walpack ridge lengthwise into two ridges, one of which, next the river, is short

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N. E. 200 rods; then S. 50 rods (to Decker's Ferry at the mouth of Flatbrook creek); then S. 65° W. to the Delaware Water Gap. (215, G6.) The former continuation of the river along the north foot of the ridge southwest to Stroudsburg will be discussed in chapter 85, on Marcellus shales.

* This cross clearage is a characteristic feature of this formation; and it is well exhibited in the high bluff on Shawnee creek, at H. Overfield's, where the Caudagalli grits juts out over the Oriskany sandstone.

† Near the Cartright school house, a large surface alongside the road show them S. 60° W.

‡ This table of rock is at the roadforks. The pebble rock is quite calcareous. Its top surface is polished, scratched and grooved in a direction of ice movement S. 50° W. For a cross section of the Hogback at Walpack bend, see the first figure on Pl. CXXXI above.

CXXXI.

No VII, Oriskany sandstone, shales & iron ore. Sections in Monroe county

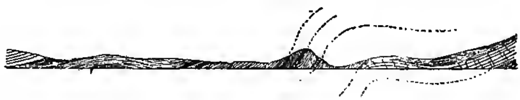


Fig 6 Section through Stroudsburg across Walpack Axis.—1 inch = 1¼ miles

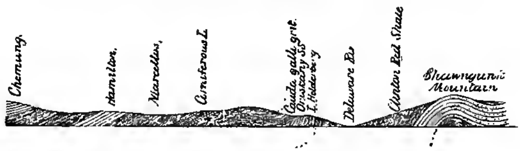


Fig. 7 Section S.W. of Walpack Bend.

Fig. 3 Godfrey's Ridge S.W. of Stroudsburg.

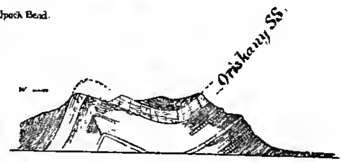


Fig. 4 Godfrey's Ridge, S.W. of Stroudsburg

No VII Glass sand quarries in Huntingdon Co.

Blair county Oriskany limonite

J. Bell's iron ore mine

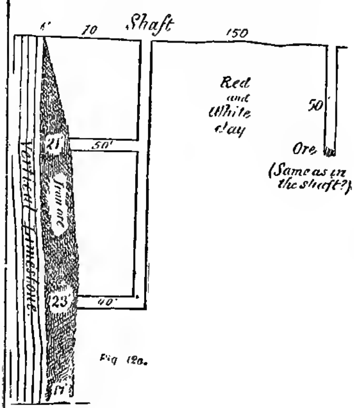
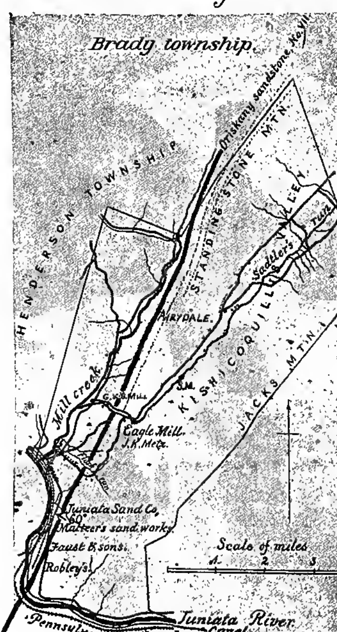


Fig. 12a.



and high; the other, back of it, overlooks the valley of Pond creek, is cut by Marshall creek, and ends in an anticlinal nose where Sambo run enters Broadhead creek a mile above Stroudsburg. Three such anticlinal rolls, coming from the west, cross Broadhead creek, and Marshall creek, and broaden out the ridge of No. VII to a width of more than two miles.* South of each roll is a shallow basin, holding *Corniferous limestone beds*, pointing up east into the air. The southernmost of these make Buttermilk falls on Marshall creek at Experiment mills.†

Mosier's knob (1175′ A. T.) is the much frequented summit of the ridge next the river, 1½ miles east of Shawnee village; being 865′ above the river. It affords a grand prospect. Its rocks are *Caudagalli*, like the whole top surface of the ridge; but the underlying *Oriskany* crops out in a cliff 400 yards southwest of the knob. dipping steeply N. W. and 900′ A. T. In the north slope of the ridge under the knob, the *Oriskany*, 20′ thick and quite pebbly, juts out 100′ above the creek level (600 A. T.), over 30′ of impure, cherty, shaly limestone beds (*Stormville shales*) holding *Spirifera macropleura*. Similar cliffs run along the face of the opposite (northern) ridge.

Between Shawnee and Marshall's creeks the ridge is an outcrop of *Oriskany* with a north-facing of *Caudagalli;* the overlying *Corniferous* making Buttermilk falls, a charming slope of broken-water 35′ high, at an angle of 30° facing the spectator, over the sharp edges of limestone strata studded with large masses of black flint. Here are Track's mills.

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*These rolls may be regarded as one anticlinal, namely that which crosses the Delaware below Walpack bend, and makes eastward through New Jersey, crimpled or flattened out along this part of its course. From Broadhead's creek westward, it begins to assume the immense proportions and lopsided shape which it wears through Carbon county, crossing the Lehigh river at Weissport; to be described in the chapters on No. VIII.

† The fall of 15′ which Shawnee creek makes at Shawnee village, a mile above its mouth, is not over *Corniferous* (No. VIII) but over *Stormville* limestone (No. VI); the *Stormville conglomerate* being exposed just above. (G6, 245.) The valley of this creek is in fact excavated its entire length in Smithfield township in *Stormville shales;* the Oriskany cliffs coming down to the stream just above the township line.

Marshall's creek falls again 10′ over a great ledge of *Caudagalli*, in which *Atrypa reticularis* occurs.

Pipher's mill is 400 yards below Buttermilk falls, and in the opposite hill side is the *Oriskany* cliff, resting on 40′ of *Stormville lime shales* down to water level; and supporting bluish gray *Caudagalli* cliffs in a little synclinal roll along a crest south of which the *Oriskany* rises steeply to the main summit at Kurtz's quarry; the rock very pebbly and hard to work.

Broadhead's creek, a mile from its mouth, cuts square through the ridge of No. VII, which hence westward is called *Godfrey's ridge.* Here in the vicinity of Experiment Mills the following section was made (G6, 239):

*No. VII. Experiment Mills section.**

VII	*Caudagalli shales,*	visible,	15′
	Oriskany	*Sandstone pebbly* massive calcareous,	5′
		lime shales, cherty, many fossils,	38′
		quartz conglomerate,	1′
Stormville shales.	shaly limestones, dark, sandy, fossiliferous,		50′
	limestone shales, dark blue, sandy,		75′
	concealed,		25′
	limestone, massive, *cherty,*		10′
	conglomerate,		10

*The bottom measures are exposed at the great quarry of W. Croasdale near Experiment Mills, dipping 35° (S. 25° E.); the greenish limy shales, barren of fossils, outcrop on the hillside; the D. F. SS. caps the high cliff overhanging the quarry, with a steep S. E. dip. In the old Croasdale quarry, 300 yard south of the present workings, the rocks dip steeply N. W.—The *Stormville limestone* shows its upper massive cherty fossiliferous beds on the east bank of Broadhead's creek just below the covered bridge above the mouth of Marshall's creek; *Pent. galeatus, and crinoidal stems very abundant;* one bed near the bottom (3′) almost made up of *Pentameri.*—The conglomerate, just under the bridge and in the road is in 6″ to 12″ layers of pebble rock, with 6″ to 12″ parting layers of sil. calc. rock; all fossiliferous; all covered with cherty massive limestone beds, the shells badly preserved.—The overlying 125′ shales are finely exposed in the N. Y. S. & W. RR. cut just above the bridge, dipping 55° (N. W.). *These dirty gray shales* resemble the *Caudagalli shales* except that they are quite fossiliferous, the upper layers being so crowded with *ground-up fragments of undeterminable shells* as to deserve the name of limestone beds; whereas the *Caudagalli shales* show nothing but the Cock-tail seaweed. It seems absurd however to throw them into two different grand divisions (VII and VIII) merely because they are separated by the 44′ of shales and two beds of sandstone called *Oriskany No. VII* in the section. It is hard to see why any lines should be drawn in this case.

Stormville limestone	massive *cherty*, ... visible,	25′
	concealed, ...	75′
Decker's Ferry sandstone, ...		10
Greenish shales, ...		12′
Bossardville limestone group (see p. 933), ...		110′
Poxono shales	visible, . . . 5′	200′ ?
	concealed, say 195′	
Salina red shale, No. Vc.		

It is evident that the names given to the formations in this section, as in so many others, are quite arbitrarily arranged ; and that there are no distinct and precise limits to Formation No. VII along the Delaware river.* A pile of 1000′, more or less, of alternating limy sandy cherty shaly beds, with a few comparatively thin massy pebbly beds, and impure massive cherty limestone beds, intervene between the great Lower Helderberg (Bossardville) quarry limestone formation No. VI, and the great Upper Helderberg (Corniferous) limestone formation at the base of No. VIII.†

Oriskany fossils, however, large coarse *Spirifers* and *Rensselaerias*, are quite numerous in pebbly and cherty lime-sand strata at the top of the section, exposed along the RR. cut, where the 5′ rusty limy fossiliferous layers are in direct contact with the overlying hard, bluish-gray, almost non-fossiliferous *Caudagalli* beds, say 200′ thick, which occupy the ground along the creek up to Experiment mills.‡

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* Were it possible to get rid of our old nomenclature, which is not to be thought of, or were it possible to shift the original numbering of the great formations, which would introduce an intolerable confusion, we might regard the whole Helderberg formation, Upper, Middle and Lower, as No. VI; call the great Hamilton group No. VII ; and leave No. VIII, for the Portage and Chemung. But it is too late in the history of American geology to discuss such changes : and after all, they would relieve us of some inconveniences only to impose upon us others more weighty.

† This state of things gradually changes westward, as we shall soon see ; the sandstone and conglomerate layers increasing ; the limestones and lime shales diminishing ; and we then get a tolerably well defined Formation No. VII.

‡ So far as the fossils can avail to settle the limits of a formation No. VII is here separated from the underlying shales and sandstones which contain (at Le Barr's quarry) *Pentamerus*, *Chonetes*, a large *Avicula* (*securiformis* ?) *etc.* (G6. 246, 247.)

No. VII on Broadhead's creek.

Broadhead's creek, below Stroudsburg, strikes the north foot of Godfrey's ridge, turns and runs along it (N. E.) 2½ miles, and then at a right angle breaks (S. E.) through it to the Delaware. Here, at the angle above the mouth of Marshall's creek, are exposed in the walls of the ravine the following series of vertical, or slightly overturned strata, G6. 248):

VIII.	*Corniferous* limestone,*				100
VII.	*Caudagalli* grit,			250′	275′
	Oriskany.	Pebbly sandstone,	10′	25′	
		Flinty layers,	5		
		Pebbly and flinty layers,	10′		
	Stormville limeshales,			concealed,	10′
				visible,	60′

This fine exposure affords an excellent opportunity for measuring No. VII, which is suddenly turned up from the horizontal to the vertical. The *Caudagalli*, locked in between the overlying *Corniferous* and the underlying *Oriskany*, is about 250′ thick, and consists of hard, bluish-gray flags or slaty sandstone beds; the *bed-planes* much obscured by a S. E. dipping system of *cleavage-planes*, no doubt produced by the pressure strain of the upturn. The slightly *overturned Oriskany* beds, full of fossils throughout, jut out from the hill side like a huge dyke; *Spirifera arenosa* abundant; other shells badly preserved; uppermost 10′ pebbly and massive†; remaining 15′ interstratified conglomerates and calcareous sand rocks with flints. Under these appear the fossiliferous lime shales containing numerous layers of chert.

Another fine exposure occurs at the D. L. W. RR. bridge half a mile below the last mentioned section; where a ledge of it 45′ high (over 100′ of shales) consists of a top layer

* As in the case of the Buttermilk falls on Marshall creek, so here the lower hard massive beds of this formation make a dam across Broadhead's creek, 10′ high, in a series of cascades; great masses of flint pervade the rock, which dips 70° (N. 20 W.) here, but basins to the horizontal rapidly northward along the banks of the creek.

† Quarried with difficulty for the RR. bridge abutments for want of other suitable stone in the neighborhood. Some of it is so calcareous that the weathered surface peels off as a thick porous rotten coating.

(10′) of hard calcareous pebble rock, over alternate pebbly sandstone and calcarous flint layers. The bridge piers were got from the top layer, and the quarry is still worked; the stone is as hard as granite; but two sets of smooth straight joints furnish ready-made square blocks 4 to 5 feet on a side; but the surfaces are much pitted by casts of shells.

The cuts of the N. Y. S. & W. RR. show the short folds or crumples of the formation; especially the long cut, half a mile above the bridge, along the strike; where a 25′ cliff of it (over 30′ cherty limestone) makes a gentle arch 500′ wide. Here the *top layer* is *a mass of quartz pebbles and broken shells, in a cement of limestone* which weathers out and lets the pebbles and shells fall in heaps. A hundred yards further up the track the *Oriskany* comes up nearly vertical but overturned.*

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* Dr. Chance's map of the Delaware Water Gap shows the gap of Broadhead's creek, the lime quarries, the D. L. W. R.R. bridge and Shawnee road bridge, and the remarkable want of conformity in the strike of the crests west and east of Broadhead's creek gap.

The crest east of Broadhead's creek (Trausue's Knob) is out of line 700′ or 800′ to the north; just as the crest of the Kittatinny mountain is thrown northward by a warp in the strike and an increase of dip on the east side of the Water Gap. East of the creek there is a gentle anticlinal and synclinal flexure north of the 72½° dip; west of the creek the synclinal rises vertical: further west, this synclinal makes two crests, with a table land between. These irregularities are well illustrated by the curious 30° to 60° (N.48° W.) dips in the limestone quarry at the south foot of the ridge, while those in the quarry half way up the slope are 20° to 50° (S. 45° to 50° E.). Here 10′ of limestone is covered by 15′ of pea-conglomerate, which is taken by Prof. White as the base of the *Stormville shale group*, but may be considered (as at the Lehigh river, Hazardville section) the base of the *Oriskany formation No. VII.*

East of the creek, the shales *below* the limestone dip 45° to 60° (N. 17½° W.) and the conglomerate *above* it, 90°.

This *Devil's wall* behind the Delaware Water Gap corresponds to the *Devil's wall* behind the Lehigh Water Gap. It rises from 10′ to 25′ above the surface, is 51′ thick, runs in a perfectly straight line about 1300 feet (N. 72° 30′ E.) through the timber, which nearly conceals it from view, and its vertical bed plates are cut across by cleavage planes both vertical and horizontal into rectangular blocks, so that its resemblance to an artificial wall is remarkably exact. It is well worth a visit of inspection; a row of hemlocks point out its locality; and it may be reached by ascending a path which starts from the northeast corner of the road bridge for a hundred yards and turning into the woods to the right.

Dr. Chance's section in Broadhead's creek gap is as follows:—*Oriskany*

The Caudagalli bluish grey, very hard, sandy slates are exposed in the railroad cut half a mile higher up Broadhead's creek. The remarkable *cleavage* of this formation in thin laminæ across the bed-plates gave the engineers great trouble; however deep a blast hole was bored only a small blast could be obtained. The whole formation makes a vertical cliff, 250′ high, on the north bank of the creek opposite the D. L. & W. RR. fill; dip 17° (S. 20° E.); contact with the overlying *Corniferous limestone*, full of masses of black flint, seen in the creek bed.*

Godfrey's Ridge, (Fox hill) carries the vertical outcrops of *Caudagalli* and *Oriskany* from Broadhead creek westward nine miles to Kellersville; then (Cherry hill) in two anticlinal and synclinal zigzags southward 4½ miles to Saylorsburg (in front of the Wind Gap); then as Dodendorf mountain southwestward past Rossland (2 miles), as Chestnut ridge past Kunkletown (8), Little Gap (in Carbon

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sandstone about 30′; Oriskany shales 150′; Oriskany conglomerate 15′; lime shales 15′ to 25′; Bossardville limestone 60′; lime shales (G^6, 340).

The upper layers of the *Oriskany sandstone* are largely of chert; the middle, tolerably pure pebbly sandstone; the lower almost entirely *nodular chert*. At the quarry one sees on the slabs casts of *Orthis hipparionyx*.

The mass underneath consists almost entirely of *lime shales*, with an occasional sandy or cherty layer; all much crushed east of the creek; but well exposed west of it, in fact visible nearly all the way up the south slope from the limestone quarry to the crest; and again in cliffs two miles W. of the gap.

The *Oriskany conglomerate* is a hard calcareous nut conglomerate ot white quartz pebbles, say 15 thick, (in the devil's wall) over it and under it are a few inches of *nodular chert*. Under the conglomerate are 15′ of *lime-shales*, and then the *Bossardville quarry limestone formation*.

*This is on the north side of the little synclinal which points east to Buttermilk falls.—To go back to the northern ridge cut by Marshall creek it is only needful to add that it is 1 to 1½ miles broad, and made up of *Caudagalli* strata, thrown into folds, and finally sinking northward under *Corniferous limestone* all along the Milford pike, never crossing the pike but in two places, and nowhere more than 500 yards south of it. The rocks are everywhere beautifully polished and scratched by the northern ice.—Marshall's creek cuts through the ridge southward, and into the Oriskany about a mile below Marshall creek P. O. From this down the Oriskany conglomerate makes a bold ledge on each side ot the stream; the Caudagalli strata making very rough cliffs over the ledge, owing to its shelving off in large plates along the cross cleavage planes. An excellent place to study this is near L. Bartron's, where the creek first cuts down to the Oriskany. Below this is a 6′ cascade over the Stormville top cherty lime shales.—The ridge east of Marshall's creek rises to 850′ A. T.

county, 12), Millport (16) and as Stony ridge to Bowman's station on the Lehigh river. The southern slope is always a steep made by the outcropping Lower Helderberg limestone at the top of which along the crest and sometimes down the northern slope *Oriskany*; below which to the foot *Caudagalli*.* A great cliff of *Oriskany;* at the crest of the ridge on the Stroud township line, overlooking the Cherry valley is 800′ A.T.† Another lofty cliff called *Mount Granite*, south of Stroudsburg, is half way up the north slope; here, the hard brown rock *full of large Spirifers* was quarried for Col. Norton's buildings; the crest of the ridge is here of Stormville shales in an arch (See Plate CXXXI above).

The *Oriskany* may be well studied in *Huffert's lower cliff*, the top portion of which has lost perhaps 5′ or 10′; for its upper surface (dipping rapidly S. E.) is planed off smooth with glacial scratches running S. 30° W. at 600′ A.T. Only ten feet of it is left.

Huffert's Oriskany section (G6, 263).

Nearly pure conglomerates; *no chert;* few fossils,		10′+
Pebble beds with *chert partings* an inch or more thick,		10′
Lime chert, with streaks of pebbles,		5′
Pebbly bed,	8 inches.	
Chert layer,	7 "	
Pebbly bed,	12 "	
Chert layer,	8 "	
Pebbly bed,	4 "	

*This is the rule; but there are sometimes folds which disturb this arrangement; for example, at J. Huffert's the *Oriskany* rising southwards rolls over and makes an upper cliff near the crest; and then another cliff 100′ lower marks the final outcrop; thus, as seen from the Blue mountain, the formation looks double. The lower line of cliffs is at about half the height of the ridge. (G6, 262; Fig. in G. P. p. ——).—At J. Marsh's. on the edge of Stroud township, is a smooth pavement of *Caudagalli*, scored with *glacial grooves* (S.25° W.) dips 8° (N.30° W.). East of this, at B. Morgan's, a little basin of *Corniferous limestone* is left on the top of the ridge. Near P. Pipper's the *Caudagalli* dips 7° (S. 25° E.) steepening (southward) to 10°, 15°, 20°, and then the *Corniferous* descends. On the road from J. Terpennings on the pike south to J. Hoffman's the *Caudagalli* comes up 25° (N. N. W.) then 20°, 8°, 5°, to the summit (750′ A. T.) and then begins to dip (S. S. E.) 5° at J. Weller's; then reverses to (N. N. W.) beyond Hoffmans, and finally the *Oriskany* comes up at the Marshall creek road near Yetter's. (G6, 253.)

† Delaware river at mouth of Broadhead's creek, low water, 1881, 394′.

Chert layer,	8 inches.		
Pebbly bed,	4 "		
Chert layer,	18 "		
Pebbly bed,	4 "		
Chert layer,	4 "		
Pebbly bed,	6 "		
Chert layer,	12 "		
Pebbly bed,	6 "		
Chert layer,	5 "	in all say	9
Very pebbly fossiliferous sandstone,			4′
Impure limestone, with *layers of chert*,			4′

The *Caudagalli grit* strata outcrop along the northern slope of Godfrey's ridge dipping northward into the valley of Michaels creek; usually steeply occupying nearly the whole slope from top to bottom, and sometimes the crest of the ridge; and finely exposed on all the roads crossing the ridge; hard bluish gray, sandy slates or flags; cross-cleft (S. E.) so as to obscure the true bedding. The top of the formation passes insensibly up into the *Corniferous* at the foot of the ridge.* The top 25′ or 30′ contains much *chert*.

In Hamilton township, where two anticlinals swing Godfrey's ridge southward towards Wind Gap, shutting up the head of Cherry valley by projecting into it two spurs, the *Oriskany* formation thickens while the *Caudagalli* and *Corniferous* formations *thin* and *disappear* near Saylorsburg. This sudden thickening of the Oriskany commences at Kellersville.† The pebbly character of the formation is best shown by the great overcoat of loose *débris* which lies upon the lower southern slope and valley, covering the outcrop of the Bossardville limestone, as described on page 932.‡

*Contact of the two formations finely exhibited in the D. L. W. RR. cut, ½ mile below East Stroudsburg, where 50′ of Caudagalli arch beneath Corniferous; also on the Stroudsburg-Water gap road; also on the Stroudsburg-T. W. Rhodes road, where *glacial scratches* run S. 40° W. Along the projected L. & E. RR. line, ½ mile east of T. Stone's, the upper surface of the *Caudagalli* is smoothed and grooved by ice (S. 30° to 40° W.).

† The *Oriskany* juts out in a cliff just northwest of Stormsville; dip nearly vertical (N. N. W.); only 25′ of top strata show, largely made up of white quartz pebbles in a coarse gray sand cement; under cliffs of *Caudagalli* (steeply crest-cleft S. S. E.) forming the crest. (G6, 279.) See Stormville section already given, page 923 above.

‡The north slope, S.W. of Bossardville is also deeply covered. The crest, a great cliff opposite J. Mansfield's, is broken and crushed, heaps of boulders covering both slopes to an unknown depth. Just N. of Bossardville the ridge culminates at 900′ A. T.

At the glass-sand quarries the increased thickness of No. VII seems to be produced by solid sand strata replacing the shales between it and the Stormville conglomerate Stormville; for, W. of Bossardville. We have here 150′, perhaps 200′, of massive cliffs under which appear a great thickness of buff brown sandy shales.*

The overlying *Caudagalli formation* has a narrow outcrop and steep dip at the east line of Hamilton township and thins away westward; but its outcrop is so hidden that its feather edge cannot be located. The overlying *Corniferous* formation seems to feather out near the Ross township line. The *Caudagalli* certainly does not exist about Rossland in the Dodendorf mountain in Ross.

A considerable ridge of *Corniferous limestone* runs along north of *McMichael's creek* from Stroud township through Hamilton township, gradually dying down westward. This ridge is anticlinal; the arch is cut through by McMichael's creek 100 rods below Kunkleville; under the arch the *Caudagalli* gray grits appear, with S. E. cleavage-planes rather wide apart.†

Godfrey's ridge loses its name in Hamilton township and becomes *Dodendorf mountain* in Ross township. The great height of the ridge (1200′ A. T. at Lessig's peak) proves the extraordinary thickening of the *Oriskany* formation alluded to above; but for 15 miles not a single stream breaks through it, and no section of it can be obtained. The deep

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* The east Stroudsburg Bottle Glass Company's quarry, on the top of Godfrey's ridge, ⅔ mile west of the road, at S. Shaefer's (825′ A. T.) has been worked for many years; rock, gray-white, coarse grained sandstone, with many darker small flat pebbles; too ferruginous for window glass (G^6, 283). The new factory (1881) gets its *glass-sand* from a quarry along the road north from G. Barger's, just south of the crest (750′ A. T.); rock much decomposed, so that when the cover of loose bovlders is removed the loose sand can be shovelled. Good *bottle-sand* can in fact be got anywhere along the Oriskany ridge from here westward into Ross township. No fossils *whatever are found in the glass-sand.* The deep deposit of *sand* under the surface covering of boulders is called "Clay" by the people; but the error is exposed by the following analysis by Mr. McCreath:—Silica 82.02, alumina and a little ox. iron 11.00, lime 0.28, magnesia 0.77, water, 2.84(G^6, 126).

† G^6, 285. This does not appear on the colored geological map of the county, which is in many other points very defective and requires thorough revision on the basis of an exact topographical survey.

valley of the Aquanchicola creek separates it from the Kittatinny mountain on the south; and the deep valley of Frantz's creek separates it from the Wire Ridge highland on the north. Where Frantz's creek breaks through it at Little Gap to join the Aquanchicola, two miles west of the Carbon county line, no section is recorded.

Dodendorf mountain is not easily explained. At the iron ore diggings at S. Lessig's west of Saylorsville the ridge is only 800′ A. T. and the surface is a bed of white sand and sandy clay, of unknown thickness, produced by the complete disintegation of the Oriskany strata. Yet only a mile west of Lessig's the ridge rises suddenly to 1200′ A. T. and its crest continues at that altitude for several miles, covered with immense blocks of ironstained sandstone in which much iron is visidle; the *débris* making a deep surface deposit down both the north and south slopes. These blocks indicate massive strata; but none such crop out at the surface; imperfect exposures indeed occur, but in a crushed or broken condition. Many fossil casts occur in the blocks, which often have a dark and almost black aspect. No *Caudagalli* or *Corniferous* strata are to be seen, nor even their fragments; so that either these formations are absent, or have greatly changed their character. Yet the overlying *Marcellus* black shales show themselves in the road along Frantz's creek. But for the most part along the whole northern slope of the Dodendorf ridge the *Oriskany drift* conceals the strata, even covering the *Marcellus*. It is therefore not entirely certain that the *Caudagalli* and *Corniferous* may not exist along the line.**

In Eldred township the *Oriskany* continues to make the crest or to outcrop on the southern slope of a ridge which is 1000 to 1200′ A. T. as far as Kunkletown, where it falls off in a wide gap, only 800′ A. T.,† the surface in which is

**The northern ice did not extend this far; the terminal moraine being some miles to the north and east. The Oriskany *débris* has merely rolled and slid down of itself into Frantz's valley, as the outcrop on the ridge mouldered away under the action of the weather; as it is still doing yearly.

† Frantz's creek being at the lower Kunkletown hotel 495′; and the Aquanchicola above Nelson's tannery 485′.

a deep deposit of pure white silicious clay from which all the iron-element of the formation has been leached out.*

In Carbon county the crest of the ridge is made by great cliffs and bluffs of sandstone, shattered and broken blocks from which, full of quartz pebbles and honeycombed with casts of large *Spirifers* and other shells, lie strewn upon the northern and southern slopes. The top layers of the *Oriskany* are concealed; and it is possible that *Caudagalli* and *Corniferous* outcrops may exist down the northern slope, at the foot of which the black *Marcellus* shales appear in the banks of Frantz's creek; but if so, they must be very thin, for several tunnels have been driven into the ridge in search of coal one of which reached the iron ore which usually lies upon the Oriskany. (See Chap. LXXXVI.)

From Little Gap to the gap at Millport (four miles) the Oriskany ridge continues to wear its ordinary wild and rugged aspect, with a sinrle crest, sharp and rocky, and side slopes, especially the southern, covered with sand and boulders which have slid from above; but there is no longer the deep valley of Frantz's creek behind it. The hill country of No. VIII is not far to the north of it, from which several small streams issue and gap the ridge, showing its strata dipping from 75°(N. N.W.) to vertical and even *overthrown* to 105° (i. e. 75° S. S. E.) sufficiently explaining their crushed and broken condition. West of Millport 1¼ miles a small stream makes a cut through the ridge; another small stream cuts through it 1¼ miles further west; and 1½ miles further the Lehigh river breaks through it, between Bowmansville and Hazardville. The cement, paint and limestone quarries are in the second little gap. A sharp roll from the east here enters the Oriskany ridge and doubles it.

That part of the ridge between the two little gaps was named by the German settlers the *Steinberg*, Stony ridge, Teufelmaur, or Devil's wall: a wall of vertical sandstone,

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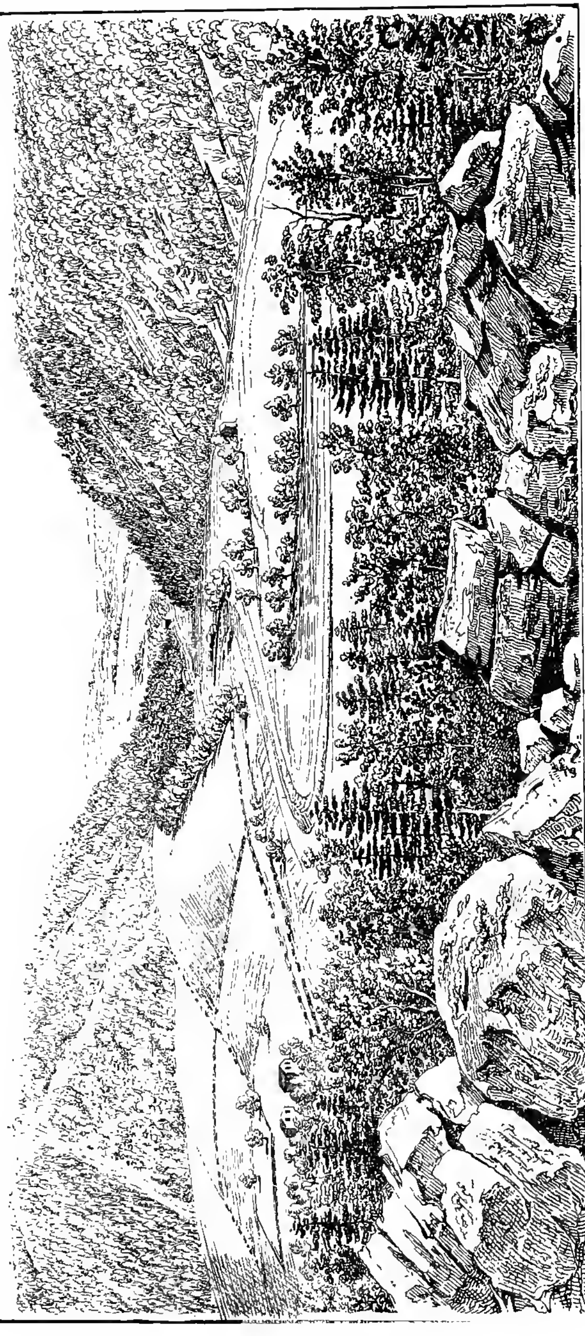
*A Frenchman some years ago filtered this clay of all its sand grains in a series of vats and sold the impalpable silicious powder under the name of "Soap." Its analysis by Mr. McCreath gave; Silica 72.8, alumina with a little oxide of iron 18.2, lime 0.3, magnesia 1.01, water 3.8 (G^6, 127).



Lehigh Water Gap as seen looking south from Rocky Ridge (Devil's wall) VII
from Lehmann's picture in Geol. Pa, 1858.

about 30′ wide and as many high, looking like the overgrown ruins of a baronial castle, and affording a marvellously beautiful prospect of the valley beneath, in which the river coming from the west and the creek coming from the east meet, turn and pass together through the Lehigh Water Gap into the southern country. In the immediate foreground of the picture stands the red conical hill of No. V wanting nothing but a watch tower to make it the guardian of the pass. (Pl. CXXXII C, p. 1062.

The geological structure of the double ridge overlooking *Hazardville** is of the most interesting character; not understood by me on the First Survey; nor shown on the colored map in Report G6; and only indicated by Dr. Chance's contoured topographical map in the pocket of that report; but well expressed by Dr. Chance's long section, a reduced copy of which is given on Plate CLI, page 1066 below.

The southern crest of the double ridge, is itself double, formed by the two outcrops of two vertical walls united below to make a U-shaped compressed synclinal trough, holding the Marcellus shales and the Paint ore beds.

The northern crest is made by the outcrop of the same rock descending N. of an overturned anticlinal. Two faults complicate the structure, and it is possible that a transverse fault is marked by a brook at the paint and cement quarry.†

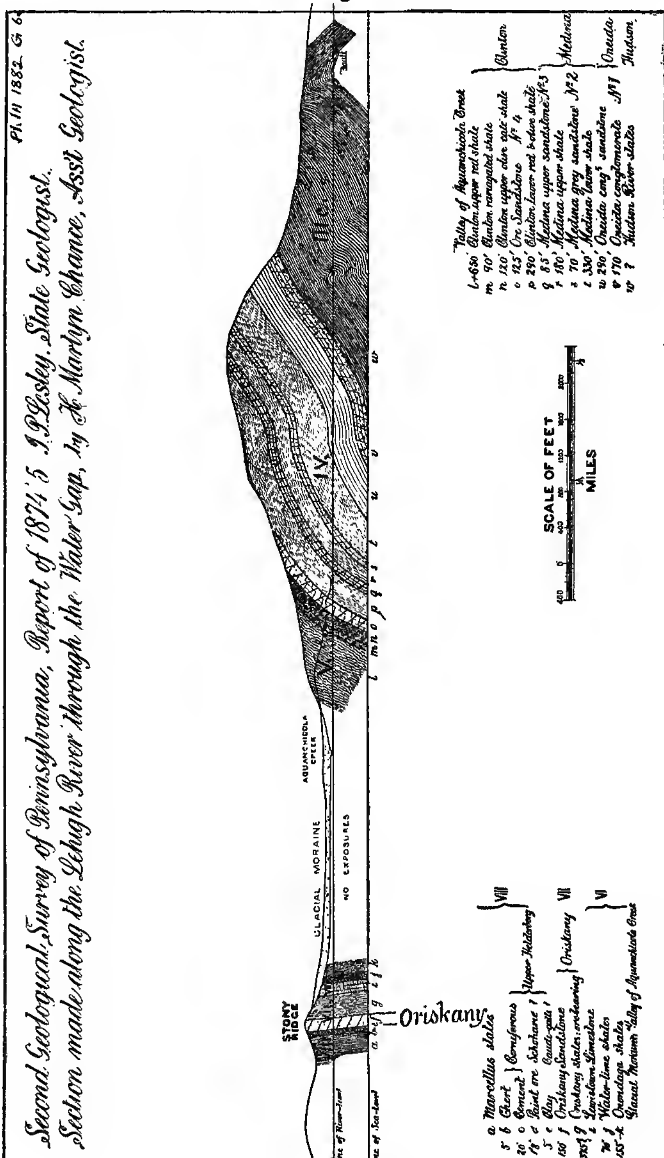
---

*Hazardville is 1 m. S. of Bowmanstown, and 2 m. W. of the Lehigh Water Gap.

†Ascending this little stream the Bossardville limestone beds on the south slope of the ridge dip 50° (N. 35° W.); at the sand tunnels the Oriskany at the surface lies flat; in the paint-tunnel the dip is 5° to 10° (S. by W.); half-way between the tunnel and the cement quarry a gentle anticlinal roll crosses the stream; the cement quarry beds dip 24° (N. 20° W.); the Oriskany sandstone quarry beds at the nose of the northern ridge dip obscurely 60°; but further on (west) in this northern ridge they are *overturned* and dip from 40° to 70° (S. S. E.)—In the southern synclinal hill the Oriskany sandstone beds are nearly vertical on both sides of the trough (Chase, in G6, 351).—The fault at the river at Hazardville looks at first sight like an anticlinal; but the *Salina* red and olive shales dip 20° (S. S. E.) and *over* them greenish and yellow shales, which really *underlie* them; it is therefore an almost complete *overturn* against a small fault. About 50 yards north of this fault the two are seen in their proper position dipping from 85° to 35° (N. N. W.)

CXXXIII.

No VII, Oriskany. Devil's Wall.



The *Corniferous* formation is here only 25′ thick.* The *Caudagalli* formation is here represented merely by a bed of clay, 3′ to 8′ thick, exactly like that to be described hereafter in the Middle Juniata valley. The *Oriskany sandstone,* 150′ thick, consists of alternate beds of fine sandstone, coarse sandstone and pea conglomerate, most of them with a calcareous cement, which is gradually dissolved, letting the rock moulder down into coarse and fine loose sand and clay, slipping down the hill slopes and collecting in the valley. Where the dissolution has not been complete the rock holds its shape but is ready to crumble at a touch. Numerous sand pits are worked to supply the iron furnaces at Catasauqua, Allentown, and elsewhere with fire brick. The sand is mostly streaked with yellow iron rust; but a few thin beds of very pure glass sand have been found.

The *Oriskany* (*Stormville*) *shales* † are here exposed for 141′; and are much thicker; there being concealed interval of 170′ down to the *Bossardville quarry limestone.* The following interesting section ‡ will show how completely they have lost the calcareous character which they exhibit along the Delaware river.§

Hazardville section of No. VII (G6, 357).

No. VII. Oriskany sandstone and conglomerate,	150′
Flint beds, one to three feet thick: some of them sandy,	24′
Stony ridge block iron ore,	2′
Flint beds, some of them sandy,	20′
Clay bed,	14′
Stony ridge red hematite iron ore,	1′
Sandstone *with Oriskany fossils, in two thick beds,*	22′
Clay beds and flint beds in alternation,	46′
Fine conglomerate sandstone,	12′
Bottom of the exposure of 141′	—

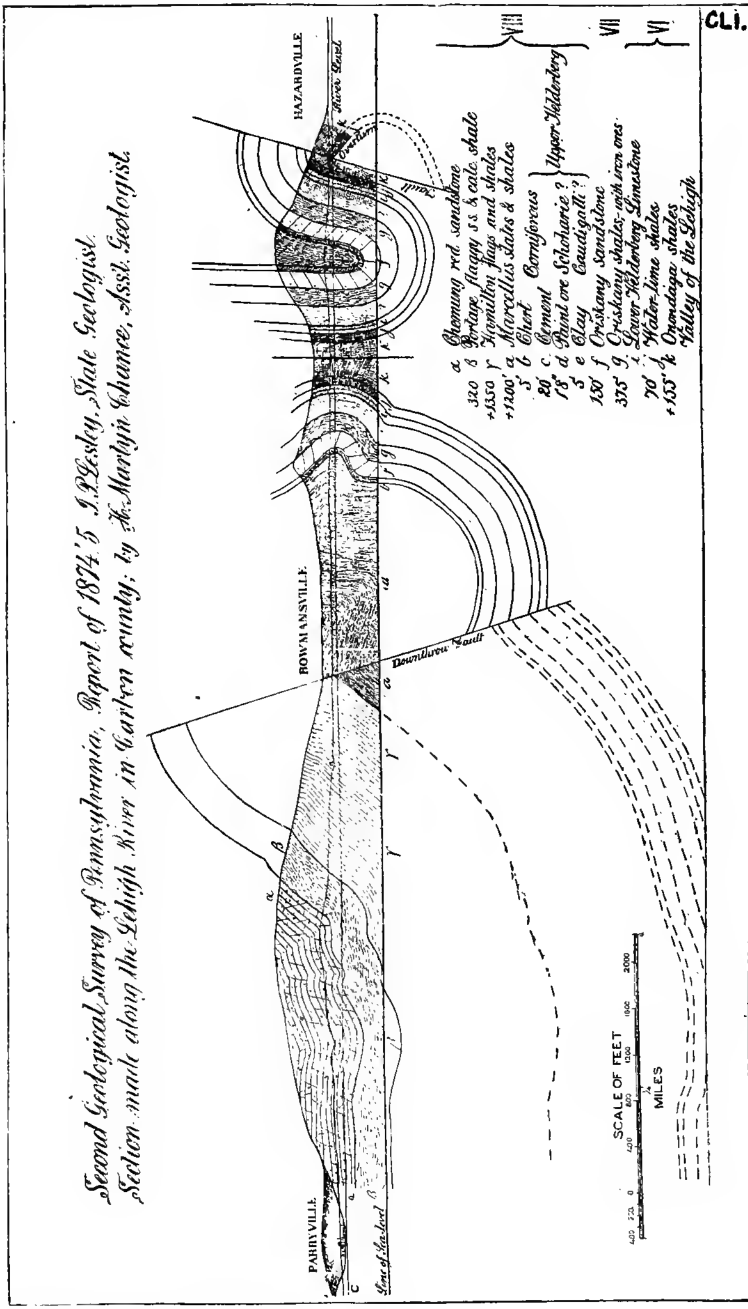
---

*Cherty limestone 5′, on top of hydraulic cement stone 25′, under which the brown hematite or paint beds 1′ to 2′ thick.

† Dr. Chase calls them Stony ridge shales.

‡ Compiled from data obtained in a prospecting tunnel on the west side of the river, and in railway cuts on both banks.

§ The upper *flint beds* correspond to those described in chapter LXX, page 970, Perry county; where the middle and lower strata are as calcareous as on the Delaware river.


CLI.
Second Geological Survey of Pennsylvania, Report of 1874'5 J. P. Lesley, State Geologist.
Section made along the Lehigh River in Carbon county; by H. Martyn Chance, Asst. Geologist.
HAZARDVILLE
BOWMANSVILLE
PARRYVILLE
River Level
Line of Sea-level
Downthrow Fault
Fault
Overturn
α Chemung red sandstone
320 β Portage flaggy s.s. & calc. shale
+1350 γ Hamilton flags and shales
+1200' a Marcellus slates & shales
5' b Chert Corniferous
20' c Cement
18' d Paint ore Schoharie ? Upper Helderberg
5' e Clay Caudigalli ?
150' f Oriskany sandstone
375' g Oriskany shales-with iron ores
i Lower Helderberg Limestone
70' j Water-lime shales
+155' k Onondaga shales
Valley of the Lehigh
VIII
VII
VI
SCALE OF FEET
MILES

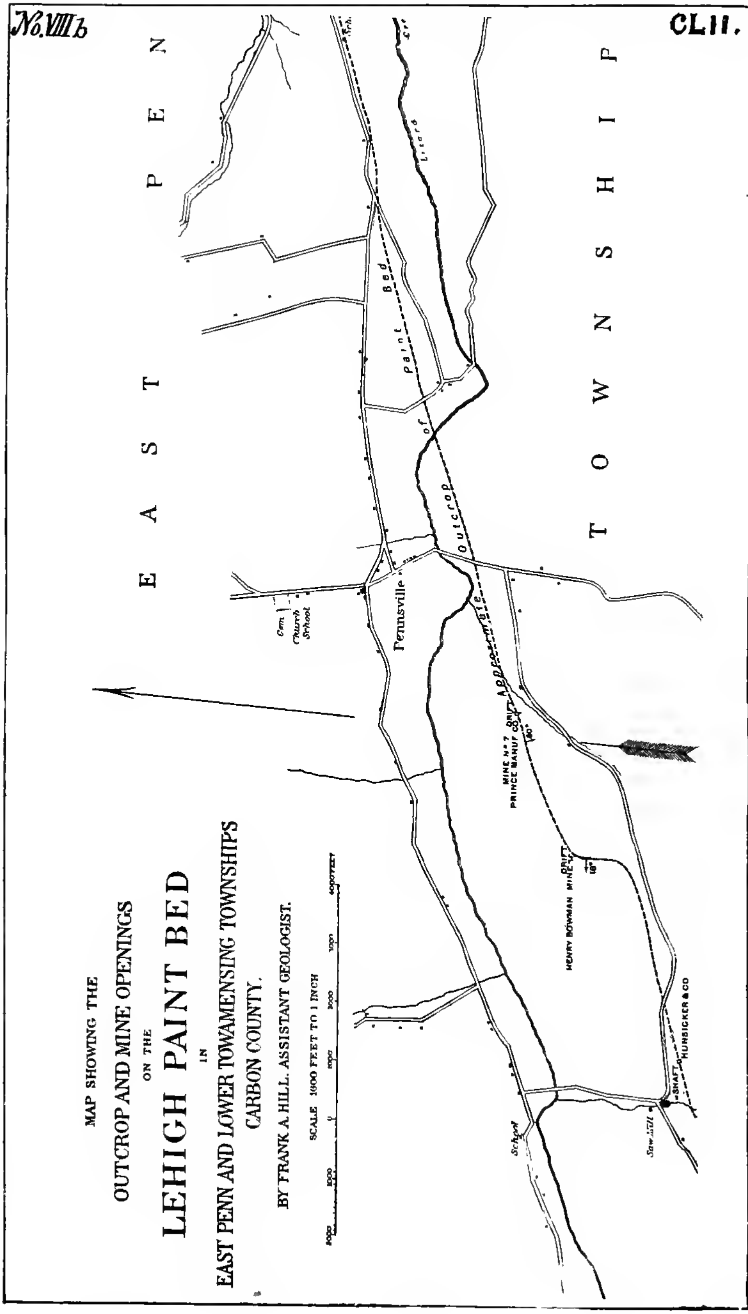
The *top flint beds* are massive, steel color or almost black, and inclined to be sandy ; those above the block-ore more so than those beneath it ; and not at all like the flint beds lower down the section. The underlying (14′) clay bed is nearly homogeneous and rests on the red hematite bed.—The massive sandstone beds are one of them coarse grained and *full of Oriskany fossil shells ;* the other fine grained without any shells.—The (46′) flint layers, amorphous, reddish brown to white, mostly pale yellow, are regular strata from an inch to a foot thick, separated by an equal number of regular strata of beautiful soft unctuous clay, streaked with iron, from an inch to a foot thick. *There is no trace of a nodular structure in the flint ;* and the exact mode of its deposit is a riddle yet to be solved. The Indians seem to have made their arrow heads from this flint.—The bottom sandstone (12′) is a pea-conglomerate (some of the pebbles reaching the size of a hazel nut) held together by a lime cement. It corresponds to the 15′ Stormville conglomerate of the Delaware Gap section. It makes no mark on the topography of the surface.

The Paint mines and Cement quarries of the Lehigh Water gap.

On the Oriskany sandstone lies a bed of clay ; on this a bed of metallic paint ore ; on this a bed of hydraulic cement ; and on this the dark *Marcellus shales.*

The interval between the Marcellus above and Oriskany beneath is only 5 or 10 feet ; the Upper Helderberg formation (*Caudagalli grit, Scoharie grit, Onondaga limestone,* and *Corniferous limestone,* as known and named in eastern New York) is therefore entirely wanting along this stretch of the southern outcrop in Pennsylvania, east and west of the Lehigh ; unless the cement layer be taken as the thinned S. crop of the U. Helderberg group of N. Y.

In the absence of fossils, it would be difficult to decide whether to consider the clay paint ore and cement as constituting the top of the Oriskany No. VII, or the bottom of the Marcellus No. VIII b, were it not for the Marcellus iron ore bed of the Juniata valley, to be described in a


No. VIII b
CL II.
EAST PENN TOWNSHIP
MAP SHOWING THE
OUTCROP AND MINE OPENINGS
ON THE
LEHIGH PAINT BED
IN
EAST PENN AND LOWER TOWAMENSING TOWNSHIPS
CARBON COUNTY.
BY FRANK A. HILL, ASSISTANT GEOLOGIST.
SCALE 1600 FEET TO 1 INCH
Pennsville
Cem.
Church
School
Outcrop of Paint Bed Approximate
MINE No 7 DRIFT
PRINCE MANUF CO
HENRY BOWMAN MINE No DRIFT
HUNSICKER & CO
SHAFT
Saw Mill
School

future chapter (LXXXVI) to which I postpone a description of the mines on the Lehigh river, condensed from Mr. F. A. Hill's report of 1886 ;* and C. E. Hesse's description in 1890.†

Plates CLII, CLIII, CLIV are placed before the reader here, however, because they give in three consecutive sections Mr. Hill's outcrop map of the Paint ore belt crossing the Lehigh river half way between Hazardville and Bowmansville; and the black line of the Paint ore stands for the outcrop line of the top of the Oriskany from beyond the Millport gap westward to more than a mile west of Pennsville. On Plate CLIV appears a columnar section exhibiting the small interval between the Oriskany and the Marcellus. From Pennsville to the Schuylkill, and so on to the Susquehanna river, we know very little about the Oriskany and its overlying Marcellus shales. No precise study has been made of this outcrop. The formation is not well developed, and it seems to be often very thin, or absent, or shaly. Even No. VI makes but a small show.

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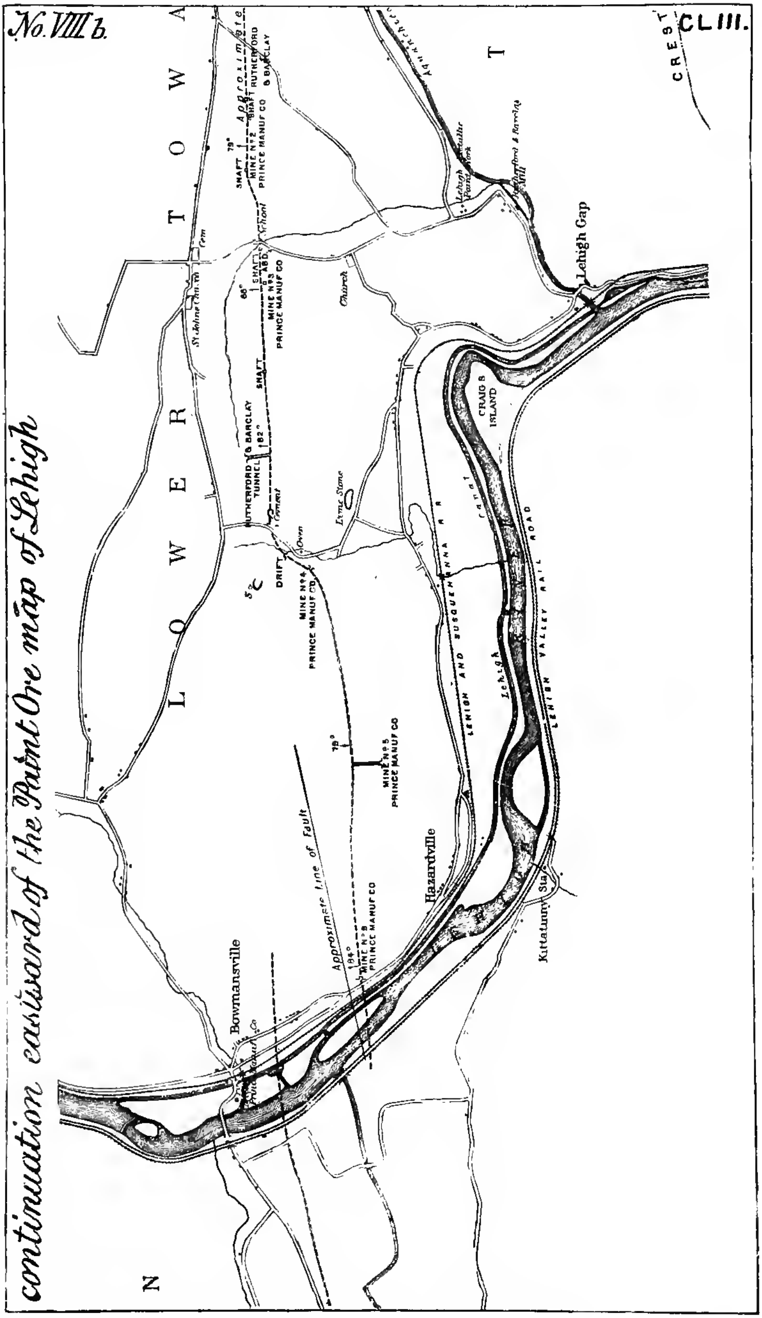
* Annual Report of Survey for 1886, Part IV, pp. 1386 to 1408, with a map, reproduced one-half linear on plates CLII, CLIII, CLIV of this volume.

† Trans. Am. Inst. Min. Eng. Oct. 1890. It will be seen however in the chapters following on the Upper Helderberg strata (VIII a) along the Delaware river, that the Corniferous limestone is well represented there. As for the Caudagalli grit, I have been disposed to consider it the eastern representative or the uppermost member of the Oriskany; both because of its sandy character, and because its cocktail seaweed is rather a sandstone than a limestone fossil.


No. VIII b.
CL III.
continuation eastward of the Paint Ore map of Lehigh
L O W E R T O W A
N
T
CREST
Lehigh Gap
CRAIGS ISLAND
LEHIGH AND SUSQUEHANNA R R
LEHIGH VALLEY RAIL ROAD
Lehigh
canal
Church
Lime Stone
DRIFT
MINE No 4 PRINCE MANUF CO
MINE No 5 PRINCE MANUF CO
MINE No 3 PRINCE MANUF CO
MINE No 2 PRINCE MANUF CO
MINE No 6 PRINCE MANUF CO
RUTHERFORD & BARCLAY TUNNEL
SHAFT
Approximate Line of Fault
Hazardville
Bowmansville
Kittatinny Sta.

CHAPTER LXXVII.

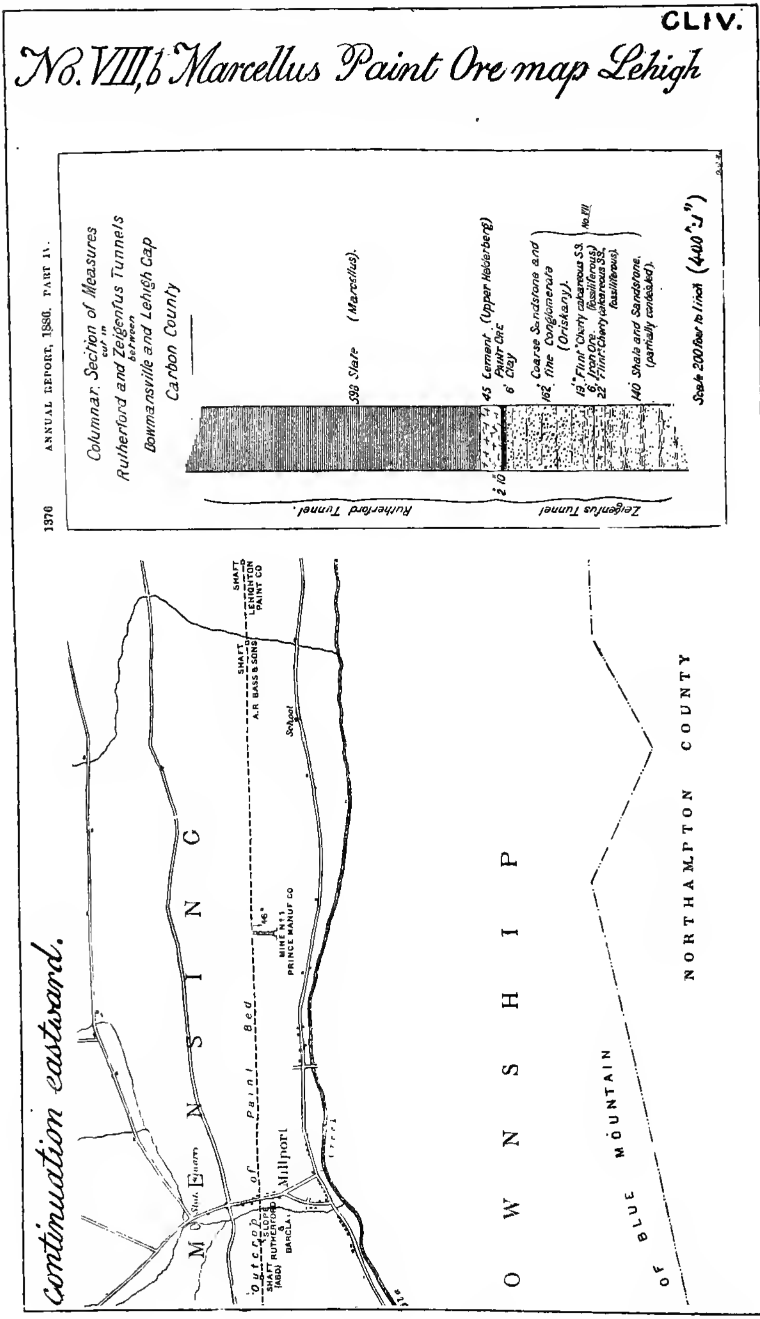
No. VII on the Susquehanna river; around Montour's ridge; in Union, Snyder, Juniata; at Selinsgrove.

The Upper Silurian formations, which are everywhere in northeastern Pennsylvania buried deeply beneath the surface, rise and show themselves on the great Montour anticlinal at Berwick where the Luzerne-Columbia county line crosses the Susquehanna North Branch, 70 miles nearly due west of the Delaware water gap. Two long low ridges of limestone No. VI run westward from this point; one, south of Montour's ridge, on the river side, past Mifflinville, Centreville, Espy, Bloomsburg and Danville, to the Susquehanna West Branch 1½ miles *below* Chilisquaque; the other, north of Montour's ridge, past Lightstreet, Little Fishing creek mouth, Mansdale, Moorsburg and Sodom to the West Branch 1½ miles *above* Chilisquaque. The southern may be called 33½ miles long; the northern 34½; and the distance across from one to the other, at first rapidly increasing to 1½ miles, continues very regularly at about 2 miles nearly to Danville, and then slowly increasing to 3 miles at Chilisquaque.

As these ridges correspond remarkably to Godfrey's ridges and its eastern and western prolongations on the Delaware, as just described,* we should expect that they would carry on their upper or outside slopes (dipping away from Montour's ridge in both directions, northward and southward) the *Caudagalli grit;* and that their crests should be made by bold outcrops of *Oriskany sandstone.* From Berwick (where they unite) westward for 13 miles, i. e. to Bloomsburg, nothing of the kind, no trace of *Caudagalli* or *Oriskany* can be found.† But from Bloomsburg

*The limestone strata have been described in chapter LXVIII.

†It is true that the overlying *Marcellus* has been deeply eroded and the limestones of VI are also much buried out of sight under ancient filled up river channels; so that some reserve must be maintained.


CLIV.
No. VIII, b Marcellus Paint Ore map Lehigh
1376 ANNUAL REPORT, 1886. PART IV.
Columnar Section of Measures cut in Rutherford and Zeigenfus Tunnels between Bowmansville and Lehigh Gap
Carbon County
598' Slate (Marcellus).
45' Cement (Upper Helderberg)
Paint Ore
6' Clay
2' 10'
162' Coarse Sandstone and fine Conglomerate (Oriskany).
No. VII
19' Flint Cherty calcareous S.S. (fossiliferous)
6' Iron Ore.
22' Flint Cherty calcareous S.S. fossiliferous
140' Shale and Sandstone. (partially concealed).
Scale 200 feet to 1 inch (400' J')
Rutherford Tunnel.
Zeigenfus Tunnel
continuation eastward.
SHAFT LEHIGHTON PAINT CO
SHAFT A.R BASS & SONS
School
MINE No 1 PRINCE MANUF CO
46°
Outcrop of Paint Bed
SLOPE
SHAFT RUTHERFORD & BARCLAY (ABD)
Millport
TOWNSHIP
NORTHAMPTON COUNTY
OF BLUE MOUNTAIN

westward traces of them begin to appear ; and before reaching the West Branch the Oriskany sandstone makes a decided little ridge and even some small bluffs on the side of the limestone hill.

From the West Branch Susquehanna westward through Snyder into Mifflin county we can follow the southern outcrop easily enough, as will be soon seen ; also the northern outcrop, which follows the loop of the No. VI ridge around Lewisburg, returns to the river a mile below Milton, and runs across Northumberland into Limestone and Derry townships of Montour county to Washington. Here the *Oriskany* is spread out over the No. VI limestone by anticlinal and synclinal rolls ; and follows the ridge in its northwest course back to the river, 3 miles above Watsontown,*

There seems, then, to be an eastern limit to the sandy deposits of this age at Bloomsburg on the Susquehanna, just as we have seen a limit to them at Walpack Bend on the Delaware. But who can venture to draw the limiting line by uniting these points upon the map, 70 miles apart? Who can tell what may be its sinuous course underground? Who would venture to suggest a belt line of maximum deposit between the Lehigh Water Gap and Warrior Ridge of Huntingdon county? And what are we to infer from the *western* limit of the formation in the Mohawk valley of New York? The underground world of geology is in such matters as dark and silent as the Hades of mythology.

No. VII around Montour's ridge.

The critical section in this district is that exposed by Fishing creek, 2½ miles above Bloomsburg.

Marcellus black slate, ...	425′
Caudagalli (?) hard sandy beds exactly like those on the Delaware, but only	25′
Oriskany (?) sandy slates and dark shales, ...	65′
Stormville ash-gray shales ; top layers, impure limestone,	35′
Lower Helderberg limestone beds of No. VI. . . .	—

*Its next great zigzag in White Deer hole and its curve around the end of Bald Eagle mountain at Muncy will be described hereafter.

Here there is no trace of the Oriskany sandstone proper.* But, to show how little can be argued from one section, it is only necessary to go a little to the west, where a magnificient section of all the formations from the top of the Chemung down to the bottom of the Clinton is exposed along Little Fishing creek, and then down Fishing creek through a gap to Bloomsburg.† Here, at the so-called *Slate quarry*, we see:

Marcellus black slate, dipping 30° (N. 10° W.), ...	410′
Oriskany ; cherty, brown sandy beds, *full of Spirifera arenosa*, ...	4′ to 6′
Stormville shales, only 2′ ; thickening in 40′ distance to . .	15′
No. VI quarry limestone (Vanderslice's) top beds, . .	25′

On the southern outcrop, the Oriskany chert boulders begin to be found in the surface drift west of Fishing creek, getting to be more abundant as we follow the outcrop westward towards the Northumberland county line. Although the rock is concealed except in one or two places, it makes a low escarpment parallel to the road. The formation where seen evidently consists of limy sandy cherty beds. (G7, 244). The *Stormville shales* under it, with a good deal of black slate, may be here 75′ or even 100′ thick. But what is both curious and important is this : at the *bottom* of these *Stormville shales*, and on top of the quarry limestones, lies a bed of *cherty sandstone* (4′ to 5′) holding the characteristic *Oriskany* fossil shell *Spirifera arenosa*,‡ and occupying the place of the *Stormville conglomerate* of the Delaware.

At the Grove tunnel, at the county line, the data are more precise §:—

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* This is the only exposure of No. VII between Berwick and Bloomsburg. Everywhere else it is concealed beneath local or river drift. But if the sandstone existed some fragments of it would be seen ; for west of Fishing creek its cherty boulders occur on the surface even where its outcrop is buried.

† This section has already been quoted for No. VI and will be quoted hereafter for No. VIII. It is given in G7, page 225.

‡ This may be seen descending the run from Appleton's limestone quarry to the Danville road.

§ The tunnel is 235 yards long. No. VII was first encounted half-way in; dip 40°, S. 10° E. ; walled up ; outcrop at surface over tunnel covered by soil ; just south of Danville road it is well exposed 2 miles further west.

Yellow gray shales,	—
Oriskany, beds, cherty and fossiliferous,	40′
Stormville shales,	100′
Sand-block (*Stormville conglomerate*), with *S. arenosa*,	4′
No. VI quarry limestone,	—

There is no mistake about the 40′, impure chert layers, separated by a few thin partings of dirty yellow rotten sandstone being *Oriskany;* for they are full of the following fossil shells :—*Spirifera arrecta*,* *submucronata*, and *arenosa*, *Discina ampla*, *Orthis musculosa*, *Leptocoelia flabellites*, *Rensselæia ovalis*, and *oblata*, *Platyceras magnificum*, *tortuosom*, and *ventricosum*, as determined by Prof. Claypole.

From Ridgeville nearly to Danville the *Oriskany* makes a sharp but low ridge (just south of the road) with a steep south slope called the Hog-back.† At Mrs. Hartzell's (on the Mahoning-Cooper township line) are exhibited :—

Gray shales, darker toward the bottom,	75
Oriskany, yellowish sandy layers, quite fossiliferous (with *Platyceras*, *Spirifera arenosa*, and *Spirifera arrecta*) at top; under which are blackish cherty, limy layers 3 to 8 inches thick.	40′
Slaty beds, ash gray (dip 40° to 45°. S. S. E.),	75′
Black slate,	5′
Shales, gray	10′

The *Oriskany* cherty sandstone makes a low ridge across Northumberland county, from Chulasky furnace on the North Branch, to the West Branch below Chilisquaque. Watson's schoolhouse, 2¼ miles east of the latter, is on a

* This is the most abundant shell in these rocks. As it is considered a characteristic fossil of the *Corniferous limestone;* and as these strata strikingly resemble the *Corniferous* of the Delaware river, lying also in the proper place, just underneath the Marcellus, they were at first considered *Corniferous* strata: but the whole list of shells above given would induce any palæontologist to accept them as *Oriskany* strata; which only goes to show how little confidence we can place in either palæontological, lithological, or stratigraphical evidence for settling a difficult local question, unless all three agree. In this case Prof. White traced the outcrop until its character changed to the ordinary Oriskany type of rock. It must be remembered also that the Oriskany is as full of chert in some other places as it is here (G 7, 298). At many localities it is a mere mass of black impure *chert* in layers from 2 in. to 6 in. thick.

† A valley ¾ miles wide and 50′ lower than the hogback, separates it from Montour's ridge. The south slope of the hogback is rapid into the Hamilton buried valley, 125′ below its crest.

bluff of it with a steep escarpment of underlying No. VI limestone looking north. Small hard Oriskany boulders are scattered along the line of outcrop. Along the Chilisquaque township line the *Oriskany* does not make a hog-back; but the south slope of Limestone Ridge, scattering its blocks along the east and west road which runs along the foot of the hill. The contact of its top cherty beds, with (possibly *Caudagalli*) light gray sandy overlying shales, may be seen in the cut 300 yards east of the Milton switch of the R. RR.*

Limestone Ridge † in Montour county has a general elevation of 250′ above Chilisquaque creek, which flows for six miles at its southern foot. The wagon road here follows the outcrop of the *Oriskany*, plenty of its fragments being in view on the surface.‡ Only one stream cuts through the Ridge in Liberty township exposing the formation 40′ or 50′ thick; the upper 10′ or 15′ being dirty yellow *shaly sandstone, only occasionally cherty;* the rest of it blackish shales with chert layers (like those south of Montour ridge, described above); *the whole formation fossiliferous throughout*, with *Spirifera arenosa*, *Rensselæria ovalis*, *Platyceras ventricosum*, and numerous *fragments of other species of shells*. At Umstead's cross-roads its *limy sandstone flags* (4 to 8″ thick) containing some *chert balls* have been quarried for *building stone*.

Chilisquaque creek cuts through Limestone Ridge in Derry township, where it is broadened by rolls and little basins. Its fragments of cherty sandstone lie about the bridge where Mud creek joins the Chilisquaque.

In Limestone township, a high *Oriskany* synclinal zigzag ridge runs east and west more than a mile; its surface covered with small blocks of the dirty yellow sandstone

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*There is plenty of room here for both Caudagalii and Corniferous; for, the genuine Marcellus black shale outcrop runs along 200 or 300 yards south of the wagon road.

† The ridge is due to the protection of the limestone against erosion afforded by a roof of hard Oriskany chert beds, which ascend its southern slope to its crest.

‡ Occasionally the dark or blackish, *Stormville* shales outcrop in the road, where it crosses a hollow and gets below the *Oriskany* beds.

beds (4″ to 8″ thick) many of which are somewhat cherty and fossiliferous. Such fragments cover also the long gentle northeast slopes about J. Shearer's and C. Boyer's ascending to L. Schuyler's.

The northernmost outcrop across Northumberland county past Turbotsville shows no noticeable difference from the above described.

No. VII in Union and Snyder.

Crossing the West Branch of the Susquehanna the southern Montour outcrop of the Oriskany is seen on Mr. d'Invilliers' colored geological map of Union and Snyder counties, in Report F3, 1891, half way between Lewisburg and Northumberland, running west past New Berlin, gapped by Penn's creek at Kier's saw mill a mile below Centreville (dip 10,° south), over Benjaman Moyer's quarry at Port Ann, and north of Troxelville to the Mifflin county line 2 m. N. of Bannerville.

The northern Montour outcrop at Lewistown makes a loop 3 m. W. of the river and returns in Northumberland county 1½ m. N. of Lewisburg; the loop being filled with Marcellus shale.

Two other long outcrops of Oriskany cross Snyder county one on each side of the Shade Mountain anticlinal. The northern line crosses the river 2 m. above Selinsgrove; Penn's creek at Schoch's mill; keeps on west north of the railroad to Middleburg, Beaverton and McClure to the corner of Mifflin county.

The southern line crosses the river a mile below Selinsgrove; Middle Creek ½ m. below Kantz; runs straight on 1 m. S. of Freeburg to 1½ m. beyond Freemont; where it makes a synclinal and anticlinal zigzag and strikes the Juniata county line at the United Brethren church on W. Mohantongo creek. Here it is 2½ miles south of the summit of Shade mountain and dips 10,° S.

There is a short outcrop of VII across the north end of Union county about 3 miles long from the river a mile above Uniontown.

No. VII is seen in but one other place south of Mifflinburg, where it forms the sharp crest of a synclinal ridge of No. VI limestone about 6 miles long, dipping between 10° and 20° both ways into the center line of the ridge.

Along all these lines No. VII sandstone forms the crest or coping of the outcrop ridges of No. VI with its innumerable small but important local limestone quarries, already described or noted in the report.

Character of No. VII in the four counties.

The low ridge is everywhere a visible feature of the landscape, and carries a peculiar soil, although the formation is extraordinarly variable in thickness, i. e. in the number and size of its sandstone beds, and the number and thickness of its sandy shale partings. In Union and Snyder the upper sandstone mass varies from 20 to 60 feet. Where thin, it weathers to loose sand spread abroad upon the slope of the ridge the crest of which is thin limestone; where thick and more resistant it makes itself the crest. In Mifflin and Juniata counties we will see it increase to 125′ and 150′. The lower sandy shale mass varies from 75 to 125 feet, supporting the sandstone crest where that is thick, and mingling its sand with that of the sandstone on the other slope where both are thin. Where the sandstone is thick the shales outcropping are buried beneath its weathered fragments on the limestone slope. This is generally true throughout the four counties, because the Oriskany at most localities of the district is a hard flint or chert rock breaking up into sharp irregular pieces, making a hard dry soil very light but rarely farmed. But in numerous places the beds are made up of loosely cemented grains of sharp quartz, furnishing glass sand.*

‡ Mr. d'Invilliers' Report F3, p. 51.—In Union the Oriskany is a thin bed of loose sand. In Gregg county, where low dips spread it out. In the Lewisburg synclinal it is a mass of yellowish brown sand on the limestone slopes. Along the Mifflinburg synclinal ridge it is discolored and shaly, 25′ to 30′ thick, with no supporting flinty shales at all.—In Snyder, it is generally a worthless chert, sometimes thin, or wholly absent. On the S. side of the Northumberland synclinal it sometimes shows a thin bed of good sand; but the whole length of the outcrop is practically worthless. In

An iron ore, some little of which has been mined from the upper part of the Oriskany sandstone in two or three places in Mifflin county, will be mentioned further on. In Juniata county the ridges of VII are occasionally strewn with attractive but worthless masses of sandy brown hematite ore.

No. VII on the Selinsgrove anticlinals.

Near Selinsgrove, the great *Shade mountain anticlinal* brings to the surface, on the two sides of the No. VI limestone arch, two outcrops of No. VII, a mile apart, which unite eastward in a sandstone ridge terminating at the Little Shamokin creek, 4 miles east of the river, in Lower Augusta township, Northumberland county, 4 miles south of Sunbury.*

Here we see the consistency and sufficiency of our geological nomenclature brought into open question. The presence of a couple of fossil shells throws it into confusion. The variability of the rock strata in thickness and character, makes it impossible to establish a satisfactory classical order.

The *Oriskany sandstone formation* is here plain enough ; but shall we call the 140′ of gray shales over it *Caudagalli* or *Marcellus ?* the 65′ of limestone over them *Corniferous*

Flint Ridge the high crest is made of about 40′ of hard chert.—In Mifflin it will be described further on.—In Juniata its outcrops are usually flinty. Flintstone Ridge zigzags east of the Juniata river from Richfield to Port Royal : large accumulations of sand taking place at ends of the synclinal basins ; but the average thickness sandstone is only 40′ ; and of the underlying shales, here both calcareous and siliceous, quite hard, breaking down into small sharp edged square pieces, about 40′ also.—Along the S. side of the main Tuscarora synclinal, along the foot of Turkey Ridge, the Oriskany is scarcely perceptible. W. of the Juniata two chert ridges flank the main valley all the way into Huntingdon county ; rarely farmed but given up to peach orchard horticulture ; the sandstone here 20 to 25′, the shale 40′ to 50′ —In the extreme S. E. corner of the county VII makes the crest of the Tuscarora mountain anticlinal at McKee's Half Falls.

*The arch is shown in Plate XXVII, G7, p. 342, reproduced (reduced) on plate CXXII on page 1080 below (See also G7, 360, 362). The geography is confusing on account of the curious way in which the line between the two townships has been drawn ; Upper Augusta having been allowed to retain most of the limestone land south of where the line, if continued for a few hundred yards westward, would have struck the river bank. A survey of this neighborhood is much to be desired for properly locating the geological outcrops.

CXXII.

No. Vc, Salina, Bloomsburg red shale. I. C. White.

Fig. 97.

Sections along the Northern Central Railroad. Fig. 98.

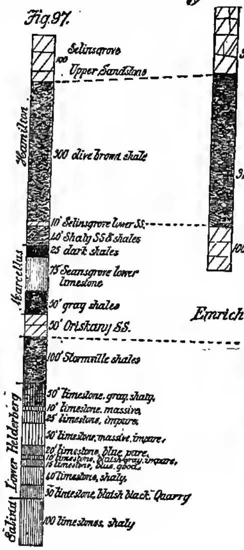


Fig. 99. Emrich & Lebo's quarry.

G7.

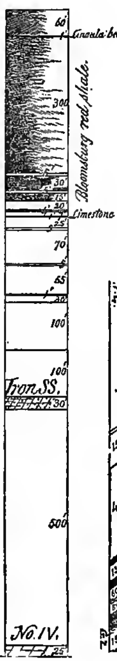
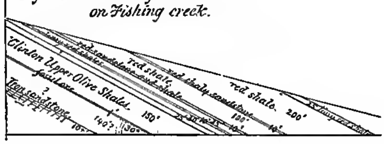


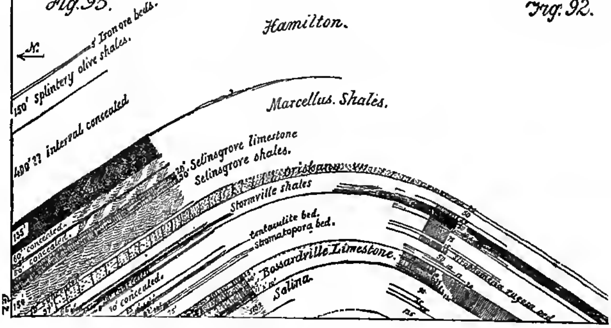
Fig. 91. Section at Chulasky furnace, in Point township, Northumberland county, Pa.

Fig. 72. Bloomsburg Iron Co's R.R. section on Fishing creek.



Section along the railroad, across the Selinsgrove anticlinal.

Fig. 93. Fig. 92.



or *Marcellus?* and that merely because in the latter is embedded the Corniferous *Leptocœlia acutiplicata* side by side with the Hamilton *Ambocœlia umbonata?* Here then we see repeating itself *above* the Oriskany the embarrassment produced *beneath* the Oriskany by the Stormville shales. Prof. White in his report G7 avoids it by giving the local name *Selinsgrove shale* to what may be *Caudagalli grit;* and *Selinsgrove lower limestone* to what may be *Corniferous limestone*, over which lie unmistakable *Marcellus black slate* 300′ thick. The Marcellus is a fixed horizon above; the Oriskany is a fixed horizon below; it matters little what we call the interval of 200′. The important point is that this interval is subdivided here into a limestone formation above and a sandy shale formation below; and for all practical purpose the upper subdivision can be regarded as an extension into Pennsylvania of the New York *Corniferous* no matter what are its fossils; and the lower subdivision can be regarded as an extension into Pennsylvania of the New York *Caudagalli* no matter what are its fossils.*

We have seen on the Delaware at Carpenter's Point, under *Marcellus* shales 800′, *Corniferous* limestone 250′, *Caudagalli* grit 315′, *Oriskany* limeshales and no *sandstone* 50′, *Trilobite* bed 10′, *Pentamerus* shales 140′, *Pentamerus* limestone 10′, and so on down through No. VI.

We have seen at the Delaware Water gap Hamilton 1200′, *Marcellus dark* shales 500′, *Marcellus gray* shales 300′, *Corniferous* limestone 200′, *Caudagalli* grit 250′, *Oriskany* limy sandstone and conglomerate 50′, *Stormville* shales 160′, *Stormville* conglomerate 15′, *Pentamerus* limestone 75′, *Decker's Ferry* group 55′, *Bossardville* quarry limestone 90′, etc., of No. VI.=2900′.

We have seen at the Lehigh Water Gap *Marcellus* variously estimated at 800′ and at 1200′, *Corniferous ?* 25′, *Caudagalli ?* 5′, *Oriskany sandstone* 150′ to 200′, *Oriskany* (*Stormville*) *sandy shale* 140′, green shale and limy sandstone 30′; *Bossardville* quarry limestone 40′, etc., down through No. VI.=1190′ to 2140′.

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* We shall see in the chapters on No. VIII that this Selinsgrove district is of great importance in discussing the variations which take place in the overlying *Hamilton* group of formations.

We have seen on Fishing creek, on the *northern* outcrop of Montour ridge in Columbia county, only 24 miles north-east from Selinsgrove, *Hamilton* 400′, Marcellus upper black fossiliferous and lower gray slates and shales 410′, *Oriskany* sandstone 6′, *Stormville* shales 10′, to the limestones of No. VI.=826′.

But on the *southern* outcrop between Catawissa and Bloomsburg, *only 2 miles distant*, we have this amazing discrepency :—*Hamilton* and *Marcellus together*, down to the place where the buried outcrop of the *Oriskany* ought to be, 2100.′

This prepares us for the Selinsgrove exhibition where the *Hamilton alone* measures 2022′, the *Marcellus black slate* 300′, the *Selinsgrove lower* (*corniferous ?*) limestone 65′, the *Selinsgrove* (*Caudagalli ?*) gray shales 140′ and the *Oriskany sandstone* 57′, as shown in the following section (G7, 345, and page plate 342.) = 2584′.

Selinsgrove section (*north dip*).

Selinsgrove (*Corniferous ?*) *limestone*, bluish gray,*	20′
Limestone, impure, gray, with much shale, ...	30′
Selinsgrove (*Caudagalli ?*) sandy shales, bluish and gray; uppermost 30′ somewhat limy, ...	150′
concealed,	20′
Oriskany, dirty yellow, cherty, limy and sandy beds, fossiliferous, ...	57
Limy, cherty beds, interstratified with much gray shale, . .	55′
Lime shales, ...	5′
Lime shales, buff and blue, impure, ...	10′
Dark shales, with abundance of seaweed (*Buthrotrephis ?*),	10′
Lime shales, ...	10′
concealed,	20′
Limestone, impure, ...	5′
concealed,	90′
Limestone, impure, massive, ...	26′
concealed,	10′
Limestone impure, ...	2′
Limestone, shaly, partly concealed, ...	7′
Limestone, blue-gray, with *Tentaculites irregularis* and shell fragments, ...	1′
Limestone shaly and lime shales, ...	45′
Stromatopora bed, ...	10′
Limestone, blue-gray, massive, ...	10′
Limestone, gray, weathering into nodules, ...	75′
Bossardville limestone group (No. VI.), ...	133′
Salina strata (No. V), ... visible,	115′

*Once quarried by Beekon & Lantz for lime.

At Georgetown, 12 miles below Selinsgrove, No. VI is brought to the surface by two rolls on the north slope of the great Tuscarora anticlinal which separates the southern and middle Anthracite coal basins.* On each side of each roll runs an outcrop of No. VII (four outcrops in all) for several miles eastward into Northumberland county (as described in the chapter on No. VI, page 957 above.†

Here, in the south dipping Fisher's ridge, we have under only 450′ of *Hamilton*, and only 25′ of *Marcellus* dark shales, *Corniferous (?) Selinsgrove lower lime shales* 75′; *Caudagalli (?) gray shales*, 50′, and *Oriskany sandstone*, 50′ rather massive *only slightly* cherty, with *Spirifera arenosa* and *Rensselæria ovalis* quite abundant, and other badly preserved shells.= 650′.

In Swartz's ridge, north of Hickory town is the following section :‡

Emerick & Lebo's quarry section (G7, 375).

Oriskany sandstone, yellow gray, with some chert; visible,	40′
Stormville (Oriskany) shales, ash-gray to dark brown, some limy, some cherty; abundance of *Spirifera macropleura* and *Strophomena depresso*, ...	75′
Limestone beds, massive, with concealed intervals, ...	92′
Stromatopora bed, full of various corals, ...	10′
Bastard limestone, at bottom of a group of, ...	45′
Black limestone, very pure (No. VI), ...	25′

* *Four rolls* in fact here cross the river; a high double roll at Georgetown, a low single one a mile or two above; and a low single one a mile or two below at the 119th mile post on the RR., and this one probably represents the central axis of the Tuscarora mountain anticlinal.

† The long pointed loop of *Fisher's ridge*, a mile wide on the river at Georgetown, extends 6 mile into Jordan township. The long oval of *Swartz's ridge*, pointed at both ends, extends 8 miles from the river eastward. Fisher's ridge is continued on the west side of the river in Juniata county, and comes to a point westward. The northern Oriskany outcrop of Swartz's ridge forms the line between Jackson and Lower Mahanoy townships, and between Washington and Jordan townships.—The *Oriskany* sandstone does not make these ridges. They are made by the much more massive *Selinsgrove upper sandstone*, helped by the *S. lower sandstone;* the *Oriskany* being far down the slopes; as opposite Hickorytown (dip 40°+ S.); at J. Sheffer's & E. Byerly's; again north of B. Byerly's (S. dip).

‡ In Lower Mahanoy township, along the road near the Jordan township line, G7, 374, 375. Here the *Oriskony* makes a prominent ridge and holds *Spirifera arsnosa.*

Chapter LXXVIII.

No. VII, Oriskany on the Lower Juniata in Perry and Juniata counties, and its continuation in Fulton county.

In Perry county, Liverpool township, No. VII rises again to the surface on the Tuscarora anticlinal, which throws off two outcrops diverging westward, one with a north dip into Juniata, the other with a south dip into Perry county. This latter we shall now follow to and fro along its long and pointed zigzags, leading us gradually southward to its southermost and final outcrop along the Blue (North, Kittatinny) mountain, four miles above Harrisburg, and so back to the Swatara, Schuylkill, Lehigh and Delaware water gaps.

The Oriskany forms everywhere the crests of the *Lower Helderberg limestone* ridges which constitute these zigzags, and the courses of which have been sufficiently described in preceding chapters on No. VI, page 967 above. Its variations in force and character will appear from the local county sections, taken in their order along the line of outcrops.*

Nowhere in Perry county is the *Oriskany sandstone* more than 25′ thick. (F2, p. 62.)

The *Caudagalli grit* is nowhere recognized; so that in this district No. VII is confined to the *Oriskany sandstone;* unless it be extended downward to include the *White and Yellow Flint shales*, a description of which has been given in connection with the underlying *Clark's mill limeshales*, in preceeding chapters on No. VI, page 967 above.

The Corniferous formation also is absent unless it be represented by what Prof. Claypole calls *Marcellus;* so that the *Oriskany sandstone* might be said to be immedi-

* Made by Prof. Claypole. In his Report, F2, the townships are described in alphabetical order.

ately overlaid by the *Marcellus* formation; to be described hereafter with the other subdivisions of No. VIII.*

In Liverpool township *Turkey ridge* and *Wildcat ridge* come together three miles north of Liverpool, about two miles before reaching the Susquehanna river; are made by the massive *Selinsgrove* (*Hamilton*) *sandstone* formations; and enclose *Pfoutz valley*, 9 miles long, and 2½ wide on the Juniata river above Millerstown. Around the inside edge of the valley runs the supposed outcrop of *Oriskany;* but it does not show itself; the *flint beds* under it making the little subordinate ridge.

Near Millerstown in Greenwood township, where the Oriskany outcrop crosses the Juniata, it is so thin as to make no mark; only a few fragments of it can be here and there discovered among the innumerable flint slabs which cover the ground; in fact it is doubtful whether it exists at all in the eastern part of this or in Liverpool township; although it is well exhibited a few miles distant at Georgetown as stated above.†

In Tuscarora township, where Raccoon ridge is the continuation of Wildcat ridge, the Oriskany makes little show; but on the Juniata west bank opposite Millerstown it crops out with a 45°± south dip.

On the Saville township line its insignificant outcrop is sharply zigzaged by two tightly compressed arches and two basins, and then it runs on again as before westward past Ickesburg; and is again zigzaged before crossing into Madison. (See the cross section on F2, p. 398.)

Crossing Madison township the outcrop reaches its extreme west point at the Jackson township line;‡ turns in the center of the great synclinal, and returns to the Saville line south of Sandy Hill village; is here zigzaged twice and then makes a continuous fourteen mile nearly straight run on the south side of the Buffalo Hills (of VIII) to its

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*See the curious sections in Madison township, F2, pp. 250, 252, etc.

† This is an argument for regarding the *Flint group* as representing the *Oriskany*.

‡ Where it caps the end of Sandy hill overlooking Blain; the hill being a synclinal rising westward and throwing the Oriskany into the air.

two sharp zigzags in Centre township. In Madison the formation consists of soft sandy strata; making no ridge and often hard to trace; ferruginous and fossiliferous; of a deep yellowish red color, producing a narrow belt of very sandy yellow soil; its dips not very steep as it rolls over the small folds, which vary the basin form of the great synclinal and produce the zigzags. But in the absence of the Oriskany outcrop it would be difficult to make out the zigzags.

Here the Oriskany is directly overlaid by a slaty liver-colored bed of *iron ore*, 2′ thick, overlaid in its turn by a pile of limeshales 65′ high, on top of which comes solid limestone. (Centre Mills section, F2, p. 262, to be described hereafter.)

In Centre township the *Oriskany sandstone* can be best studied. Its parallel outcrops, connected at their eastern and western ends by short sharp zigzags, produced by numerous closely compressed local folds (as shown upon the geologically colored county map, and by dotted belts on the page plate township maps in Report F2) make narrow-crested rocky little ridges, worn by the weather in many places into ranges of rude columns called *Pulpit rocks*, which lend piquancy to the otherwise beautiful and lovely picturesqueness of the region around the county seat of New Bloomfield * They contrast well with the smoothly rounded outlines of the surrounding hills of shale and limestone and the well cultivated intervening valleys; and many of them, buried in woods, invite the exploration of the artist as well as of the geologist.

Yet this interesting layer of sand rock, for it hardly deserves to be dignified with the name of a formation, never exceeds 20′ in thickness. But its solidity retards its destruction; and even where frost and vegetation have widenened its cleavage planes and toppled over its massive blocks, they lie where they fell subject to a slow dissolution of their cement until they are reduced in the course of ages to heaps of loose sand.

* They will not however compare with those of Warrior's Ridge in Huntingdon county, to be described further on, where No. VII is a much thicker although not more massive formation.

In some places it is a flinty hard sandstone, white, yellow or red; in others a *conglomerate* of small rounded quartz-pebbles, resembling in appearance little white beans, mixed with a small proportion of somewhat larger ones. The rock is usually hard, but often soft and crumbling, easily quarried and crushed, the pebbles having been formerly much used for rough-casting the frame houses of the town. The sand is still used for mortar, as the rivulets of the neighborhood furnish no sufficient supply; but it is not sharp glass sand. Every grain is rounded as if by running water, like the smaller and larger pebbles; and this is the chief reason for the indistinctness of the outcrop lines in many places.*

The mode in which the long narrow synclinal outcrops of No. VII are caught in the folds of No. VI in Limestone ridge north of New Bloomfield will be best understood by the small map and cross sections, (F2, 174, 176, 178), reproduced on a reduced scale on Plates CLVI, CLVII, to be found in chapter 85 below on No. VIIIb, Marcellus. The folds are filled with the so-called *Marcellus ore* both in Centre and Oliver and Miller townships; as they are in Spring township further south.

The northern outcrop of Centre township along Limestone ridge is continued through Miller to the Juniata below Baileysburg.† A mile beyond the river, in Watts, it curves back westward and runs along the north foot of Mahanoy ridge, through Miller and Centre, close by Bloomfield, to the west line of Spring township, near Green Park in Tyrone. Here it zigzags southward four times‡ and so back eastward again along the southern line of Centre, where it

*F2, p. 186.—Can it be that this rounded form of the grains is due to a leaching process, the silica being dissolved by waters descending through the deposits in its originally undisturbed horizontal condition, and precipitated, as *gelatinous silica*, to make the layers and nodules of flint in the underlying formations?

†The Oriskany shows two outcrops at the river; the upper one *dipping north* makes a bold cliff 20′ thick. The other *dipping south* makes a *natural dam* completely across the river, which of course so greatly interested the lumber men before the construction of the canal; that they called the high hill of No. VIII on the east bank of the river *Half Falls mountain.*

‡Making Bell's hill, N. Furnace, and S. Furnace hills.

is swallowed up, or thrown a thousand feet underground, by the long Perry county fault. Here in Iron Hill it zigzags again to south three times, and then runs southwest across Spring township just north of Sherman's creek to the Tyrone line at Oakgrove; where it makes its last double and then runs eastward along Polecat valley in Carroll to a point about 2 miles southeast of Shermansdale, where all trace of it is lost, apparently by reason of the formation thinning to a knife edge.

In Miller township, three miles south of Newport, there are *four parallel outcrops* of No. VII in a belt of limestone less than a mile wide (described in detail in F2, pp 267–269), along the second of which often runs a rough ridge of rocks. The third line is synclinal, and therefore double, and therefore boldly projecting from the general limestone surface on each side of it, called *Inoculate ridge*, 400′ higher than the Juniata river level.*

Inoculate ridge is the most important Oriskany outcrop in Perry county because it forms a V-shaped trough, changing into a W-shaped trough, *entirely filled with a mass of iron-bearing clay and iron ore*, steeply stratified in opposite directions parallel to the north and south sandstone walls of the trough, produced by the decomposition of the limy shales (Caudagalli, Corniferous, or Marcellus, whatever they may be) overlying the Oriskany, and extensively mined.†

In Spring township, along Sherman's creek, which makes a gap through it 1½ miles below Bridgeport, the *Oriskany outcrop* is particularly conspicuous, although its group of sandstone beds measures little more than in Centre township. It caps the synclinal west end knob of South Furnace hill (2 miles north of Bridgeport) with a bold bluff from which a fine view can be obtained of all the upper reaches

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*A fourth outcrop follows the foot of Mahanoy hill. A little fifth outcrop at the foot of Dicks hill, north of Montabello, is only a mile long, being swallowed up at both ends by the long fault,

†To be described in its various localities in the chapter on *Marcellus ore* Chapter 86. The ore beds north of New Bloomfield and those of Spring township southwest of the town, are caught in similar troughs of Oriskany.

of Sherman creek and the four ranges of Medina (No. IV) mountains of Western Perry.*

Its Sherman creek outcrop is gapped at Gibson's mill (on the east line of Spring township, 2 miles south of Perry furnace); again at Falling Spring; again a mile further west; is folded into a short zigzag at Warm Springs; is gapped by Sherman creek; and runs round the high synclinal (No. VIII c Hamilton) knob at Oak Grove furnace looking (west) up Green valley between the No. IV mountains.—Everywhere it is a *fossiliferous*, hard, rough, ferruginous sandstone; and from it issues the great body of cool soft water at Falling Springs.†

Oriskany Fossils in Perry county.

The *fossils* of No. VII are mere *casts* of shells, mostly indistinct, difficult to recognize, and hard to obtain unbroken as hand specimens. Its coarse hard massive blocks are often completely honeycombed with these casts, from which the shells have been dissolved out and carried off by the acidulated rainwater which has found no difficulty in percolating freely in all directions through the sandy and gravelly layers. The abundance of this kind of animal life in Oriskany times cannot be mistaken; but it is not easy to explain how so vast a proportion of the shells were broken into fragments. The larger and coarser species like *Spirifera arenosa* were buried whole, and their casts are tolerably perfect; but the thinner and finer forms seem to have been broken up and even ground up and mixed with the sand by the action of the waves. ‡

Just under the *Oriskany sandstone* the *Whiteflint group* (10′ thick) is often *crowded* with casts of *Spirifera macro-*

* It is here curiously broken and slightly displaced by the western end of the long Perry county fault.

† Temperature observed Oct. 27, 1883, 55° F. On the same day the temperature of the three Warm Springs was 65°, 61°, and 60°, in an order from east to west (F2. 348).

‡ In other parts of the state and in other states, No. VII furnishes a great abundance of species and specimens in excellent preservation. Prof. Claypole supposes that the Perry county area represents a very *shallow* portion of the sea (partly in fact out of water) greatly affected by the action of storm-waves. F2, p. 190.

pleura and *Strophomena rugosa*, and other less abundant forms, (F2, 62.)* The whole Flint formation (100′ in Perry county) so abundantly exhibited on the Delaware, is not recognizable on the Upper Juniata in Huntingdon county.

No. VII iron ore in Perry county.

Iron ore does not exist in the Oriskany sandstone itself; but its layers are generally iron-stained, and some of them are very ferruginous, broken blocks being often coated with a shining black crust, which has led to much useless mining. The ore already mentioned as filling the narrow troughs of Oriskany must be considered the result of the decomposition of the overlying shales, and should be described perhaps as *Lower Marcellus ore*, for it *underlies* the limestone beds; whereas the *Upper Marcellus ore overlies* the limestone, and underlies the black shales. If the limestone be considered *Corniferous*, then the lower ore horizon would be *Caudagalli.*†

No. VII, Oriskany in Juniata county.

In Juniata county two outcrops of *Orsikany sandstone No. VII* run from the Susquehanna southwestward into southern Huntingdon and Fulton counties, one on each side of the long narrow and nearly straight Tuscarora valley synclinal; but the formation is of insignificant thickness, as we have seen it to be in Perry county; and in fact in eastern Juniata and southern Snyder it is sometimes entirely absent. In southwestern Juniata, and in Dublin and Fell townships, Huntingdon county, it is more frequently visible, but still thin; and therefore, makes no ridge, but

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* We have seen that the *Spirifera macropleura* casts are abundant in the top layers of the *Stormville shales* (just under the Oriskany) on the Delaware in Monroe county. It occurs also in the shales below the Oriskany on the North Branch of the Susquehanna in Montour county, as we have seen already. The genus *Rensselæria* occurs in the limeshales below the Oriskany in Perry county (see description already given of the *Clark's Mills group*, on p. 970), in the upper layers of the Oriskany, and it reappears in the Hamilton formation No. VIII c.

† A detailed description of this ore is given on pp. 188, 190, F2.

merely backs with a sort of veneering the limestone ridge of No. VI. *

No. VII is well exposed at the Waterford bridge. Strata of coarse blue calcareous sandstone, full of large fossils, and turning at the surface brown, 20′ thick. overlie dark chert beds and silicious limestones. At the Waterloo gap the sandstone caps a synclinal chert-hill close to the base of the mountain. Along the road to Burnt Cabins the outcrop shows a few beds of coarse calcareous sandstone weathering an iron brown, and making an insignificent chain of low knobs. The rolls on the Fulton line produce several parallel outcrops which unite in two slender tongues pointing north about 100 yards apart. Here the limestone ridge is covered by fragments of coarse brown sandstone highly impregnated with iron. From Neely's saw mill southwest No. VII has a vertical dip, passing a few hundred yards

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* A few details from Henderson's original survey in 1839-40 will suffice. From Midde creek west of Selinsgrove to McAllisterville a distance of 21 miles, runs Flintstone ridge, the crest of which is made by the Chert beds of VI; and No. VII is visible. The two anticlinals at McAllisterville form Flintstone ridge to the south, and make it point to within 5 miles of the Juniata at Mifflintown. The Perrysville anticlinal carries the ridge back 7 miles and then brings it forward again to the Juniata at Perrysville. No sandstone of VII however is discovered on its flanks.

From Perrysville southwestward No. VI makes a continuous slightly curved ridge, all the way to Fort Littleton. Barren ridge reaches the foot of West Shade mountain 15 miles from Perrysville; from here southwestward the outcrop of No. VII is visible, but thin; the ridge being much broken; and beyond Shade gap dipping steeply into the Tuscarora synclinal.

Going back to the Susquehanna river, and taking the southern outcrop, we have to make the same observations. The little Georgetown anticlinal at the mouth of West Mahantongo creek exhibits no sandstone. Along Turkey ridge there are 40 or 50′ of dark colored knotty rocks belonging to the chert beds of No. VI; the upper layers containing *Spirifera* (*Delthyris*) *macropleura* very abundantly, the characteristic fossil of No. VII. From the Juniata at New Mexico the thin outcrop of No. VII extends along Limestone ridge, the sandstone over the chert beds dipping 40° to 60° N. W. into the Tuscarora synclinal. It then saddles the little Beall's Mill anticlinal roll, and runs on straight southwest 12 miles with a uniform dip of 45° N. W. past Waterford and Waterloo, and near the foot of the high ridges of VIII; but is broken down into detached knobs along Tuscarora creek.

Beyond Waterloo it is zigzaged slightly by the dying southwest end of the Tuscarora mountain anticlinal; and then runs on straight again, keeping a few hundred yards from the base of the mountain, and nearly along the main road to Burnt Cabins. It is again zigzaged by some small rolls; crosses into Fulton and is swallowed by the great fault.

northwest of Burnt Cabins, and following the base of Little Scrub ridge until it is lost in the fault.

No. VII continued into Fulton county.

In Fulton county two Oriskany outcrops, one running along W. Shade mountain the other along Black Log mounttain, meet at a point 3 miles southwest of Fort Littleton or 2 miles east of Hustontown.*

This is the last that is seen of No. VII going south until, after 15 miles of undergound, it rises at Needmore (being brought to the surface by the Pigeon cove or Warfordsburg anticlinal) where Barrett's run circles round to meet Little Tonolowa creek. From this on, southward, two outcrops extend to the Maryland line; the line of eastdip running 8 miles S. 5° W.; the line of west dip 9 miles S. 20 W.; at the Maryland line the outcrops being 3 miles apart.†

In south eastern Fulton another outcrop of VII, issuing from the great fault at Spring valley run, runs along the west foot of Dickey's mountain (S. 10° W.) eight miles, past Elysian mills, and along Licking creek, into the southwest corner of Franklin county, turns back to make a great loop, and then escapes across the Maryland line.‡

Fulton county is therefore extraordinarily destitute of outcrops of No. VII, having only 37 miles of outcrop in all.

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* The western outcrop in Dublin county running along Plum Run ridge crosses the road a mile west of Littleton. It makes the crest of the ridge and a conspicuous knob ⅓ m. S. of the road. Northward, down Aughwick creek valley it runs into Huntingdon county, and will be referred to again. The other or Shade mountain outcrop on the road from Fort Littleton to Burnt Cabins, shows 50′ thick at Anderson's. The Burnt Cabins vertical outcrop, already alluded to, stands out like a wall from the ground, near L. Dubbs' house.

† The *western* outcrop runs along the western slope of Tonolowa ridge, the main body of the ridge consisting of the massive limestone of No. VI; is washed away in the valley of White Oak run; but shows on the crest of the ridge at the Alpine school house, No. VI cropping out finely behind it.—The *eastern* outcrop makes the crest of Stillwell's ridge (the eastern barrier of Pigeon cove). The Oriskany is in this district frequently visible only in loose fragments which show its coarse-grained and conglomerate character. Stillwell's ridge is much bolder and higher near the Maryland line than farther north. No. VII still makes its crest but in a very broken condition.

‡ The Oriskany is seen at Elysian mills rich in fossils and so calcareous as to yield lime good enough for ordinary building purposes (T2, 292).

Chapter LXXIX.

No. VII in Mifflin and southern Huntingdon.

Nothing is more surprising than the great development of *Oriskany sandstone* in the center of Pennsylvania, viz: in Mifflin and Huntingdon counties, where it reaches a maximum thickness of nearly 200 feet, and makes bold high ridges in the Lewistown valley of Mifflin and in the Aughwick valley of southern Huntingdon; and a magnificent show along the western border of the Huntingdon valley, as Warrior's ridge, crowned with its pulpit rocks. But we have seen that in eastern Pennsylvania between the Lehigh and Delaware Water Gaps there is a similar great development of No. VII, producing equally high bold ranges of hills. Between these two areas however, distant from one another a hundred miles, we have seen that the formation is either thin or absent; that it shows itself upon the anticlinals at Georgetown and Selinsgrove; but is nowhere more than 20′ thick in Perry county; only 25′ thick at Peru at the end of Shade mountain in the Tuscarora valley of Juniata county; and only 40′ thick anywhere in Snyder county.

Approaching Lewistown it becomes 110′; at McVeytown 140′; and in the long hollow descending to Mount Union 160′. At Mount Union (where the Juniata breaks through Jack's mountain) it is only 95′; and at Three Springs at the south end of Jack's mountain only 58′; but at Orbisonia it is 150′.*

The overlying "Corniferous shale" of Report F, that is, the interval between the Oriskany sandstone up to the Corniferous limestone, measures 30′ to 40′ in Snyder county;

* These measurements are intended to represent the Oriskany sandstone itself. The underlying shales, sometimes sandy without lime, and sometimes calcareous with very little sand, are treated as the upper member of No. VI; although they received in the first reports of the second survey (F, 1878) the name Oriskany shales; and are so named in the Lewistown, McVeytown, Mount Union and Orbisonia sections.

100′± in Juniata county; 133′ at Lewistown; and 110′ at McVeytown.

The *Oriskany sandstone* on Kishicoquillas creek in front of Logan's gap near Lewistown is divisible into upper, middle and lower; the upper and lower being laminated shale beds; the middle, soft clay-sandstone beds, 30′ to 40′ thick; in all 110.′ Prospect rock, back of Lewistown, is a south dipping outcrop of the sandstone. Other parallel outcrops run between it and Jack's mountain, produced by the four parallel anticlinals and synclinals to be described in connection with the Marcellus ore bed. At Minehart's ore bank 4 miles southwest of Lewistown the Oriskany sandstone lies flat, is much contorted, and contains bowl-shaped cavities on its upper surface filled with light colored clay derived from the overlying Corniferous shales, and holding a sandy ore bed (which has been mined in small quantities) varying from 6″ to 3′; analysing only 26 per cent. of iron. The sandstone itself contains a varying percentage of iron; is sometimes quite rich, but too silicious for the furnace. Further west the sandstone becomes a formation of pure white sand (F, 77).

Juniata Sand Company's mine.

The Juniata Sand Company's mine, 4 miles southwest of Lewistown, is in a bed of pure white sand, from 90′ to 100′ deep. At one place in the mine only 40′ was pure, the rest being too discolored by iron for the glass manufacturer. Gaps in the ridge also exhibit the sandstone discolored by iron. A layer of yellow sand 12′ to 18′ thick covers the pure sand. A tunnel (driven north through the underly-shales) 250′ long strikes the Oriskany dipping 46° N. W.; gangways driven to the right 100′, and to the left 400′, 15′ to 18′ wide, and 15′ high (leaving a roof about 15′ thick between them and the old surface workings) are supported by heavy timbers; these are narrow at the top and lagged closely, the roof being treacherous and liable to fall from small pockets on account of the irregularity of the cleavage planes.* Chambers driven right and left from the

* At McVeytown the timbering is not so heavy because the gangways are more arched and not so high, the sand being more solid.

gangways (pillars of sand being left) are 20′ to 25′ long, according to the quality of sand, all that is iron stained being left in. At some future time a longer tunnel starting in the still lower lime shales will take a deeper hold of the formation. The sandrock requires blasting, and breaks in falling to fine sand, so that it only needs washing by revolving horizontal agitation in water. (See description in F, 79.) The washed sand is elevated and carried to drying floors, heated by underneath hot air chambers. The mine lies 215′ above the level of the railroad, to which the sand is carried by rope traction, over 53 trestles, a distance of 420′, in iron buckets carrying each 40 lbs.

An analysis of the sand shows:—Silica 98.84; alumina 0.17; oxide of iron 0.34; loss on ignition 0.23; traces of manganese, lime and magnesia; total 99.58 (A. S. McCreath). (See comparative analysis of Potsdam No. 1 sand, and Azoic sand on a previous page.)

Dull and Bradley's sand mine.

Dull and Bradley's sand mine in the gap north of McVeytown, on the northwest dip of the Oriskany, is a pit 80′ × 80, and 30′ deep, from which gangways are driven on the strike southwest; and chambers north and south to the edges of the marketable sand. Between 1870 and 1874 40,000 tons were sent to Pittsburgh. The sandstone formation is about 140′ thick; the lower layers yellow; the upper layers bluish-gray and yellow; the middle hundred feet almost pure white glass-sand. Strata of hard solid rock make occasional ribs which are blasted and thrown aside as too hard to crush; they run irregular; and are usually lens-shaped. The whole formation is much broken, cleavage and division planes running in various directions.* What crushing is done is with heavy rolls turning in troughs or on platforms. The sand contains little clay rock, and there is little waste (F, 93).

Around McVeytown the sand is so sharp and so slightly cemented that the natural erosion by weather has made

* Wedge-shaped and pot-shaped nests of the rock are liable to drop in mining and are dangerous.

huge accumulations of glass-sand, which are mined, crushed and washed. This condition of things prevails more or less all along the north dip of the trough between Lewistown and McVeytown; and also on the north side of the troughs of Ferguson valley.*

At McVeytown the mother rock is compact enough to require blasting; but most of the masses thrown out by the blast crumbled so completely in the fall as to need no crushing. Some of the layers however have to be crushed.

Mount Hope furnace tunnel, 7 miles from Lewistown, driven through the S. E. dipping Oriskany to reach the Marcellus ore-bed, is said to have passed through more than 60′ of pure white sand. The top layers of the formation are frequently charged with iron, so that their outcrop-blocks look like masses of ore; but they are mere chunks of sandstone iron-stained or incrusted.

Long Hollow, about 3 miles long and very narrow, runs between the Oriskany ridge of the fourth synclinal of the McVeytown section and Jack's mountain. The southern ridge of the valley is irregular; and both ridge and valley are so strewn with loose rocks as to make farming impracticable. Three miles southwest of the Dunkard meeting house a gap shows the formation to be ferruginous sandrock over sandy shales. West of this gap the ridge becomes more distinct. S. of J. Rhodes' (on the S. dip) a one foot bed of sandy *iron-ore* lies upon the Oriskany; it yields only 31 per cent. of iron. Another, one or two feet thick, and no richer, lies in the Corniferous shales a little higher up. The Oriskany here measures 160′.

The Enterprise Sand Works at Vineyard station on the P. RR., 3½ m. E. of Newton-Hamilton, has 125′ of fine glass-sand which is largely quarried. The whole deposit is somewhat larger, but an impure sand bed is left unworked.†

* In Snyder and Juniata counties also the Oriskany outcrops disintegrate in this manner, and sheets of coarse sand are spread over the tops of the ridges and form part of the farming country.

† F3, 1891, p. 53. This is one of several new glass-sand mines opened and worked along this range since the survey of the field which produced Report F, 1878. The industry is greatly expanded and expanding; and every part of the numerous outcrops traversing the valley which shows both thick-

At Mount Union the Oriskany sandstone is only 95′ thick, a decrease of 65′ in a distance of 8 miles. The sandstone is yellow, coarse-grained, argillaceous; the upper portion hard, massive; the lower strata softer and very calcareous; the whole mass of rock being harder here than elsewhere.*

No. VII in southern Huntingdon.

In Huntingdon county, the Mt. Union Oriskany runs on as a prominent ridge, with a very regular and even crest (except where Young woman's creek cuts through it) for 7 miles southwestward, to a second gap in which the sandstone is displayed (from 125′ to 140′ thick dipping 26 S. E.); very fragile; consisting of alternate layers of different colors resembling the Upper Clinton variegated shales. Here the underlying shales are unusually thin (less than 20′) lying on the lime shales and limestones of No. VI.

The Lane Oriskany ore bank.

The Lane bank has been opened here on a brown hematite ore bed, varying in thickness from 6′ to 12′, which lies in the Oriskany sandstone itself about 20′ above its base.† A gangway the full thickness of the bed is heavily tim-

ness and purity of beds will become a scene of mining operations. In Wayne township, east of Newton-Hamilton, the formation is widened out at the surface by the anticlinal and synclinal rolls which are shown in the McVeytown and Long Hollow cross sections (Plates LXXXIII, LXXXIV, on pages 796, 798, above; repeated from Vol. 1, pp. 664, 646.) These rolls create a large sand flat, out of which projects small ridges made by the harder members of the series; but the sand does not seem as suitable for glass purposes here as in the more sharply tilled rocks along the south slope of the great synclinal from Lewistown west. In Long Hollow VII is 150 thick, but diminishes to 100′ at Mt. Union. No doubt many places in Mifflin county will make good mining ground when new railroad facilities permit competition with the mines along the P. RR. (D'Invilliers, F3, p. 53).

*The measurement of 95′ might be increased by taking in some of the underlying sandstone layers, which are yellow and dark ash-colored, passing into purple, pink and yellow, calcareous sand-shale, for 282′ down to the lime-shales (18′) immediately overlying the massive limestone of No. VI (F, 104).

† Of course this speaks for the calcareous character of No. VII here, the ore having probably resulted from the percolation of iron salts in the mass above and their precipitation as peroxide of iron in the place of lime which has disappeared by solution.

bered ; pillars of ore separate the working chambers. The hanging wall of the ore bed, and the foot wall also, is a shell of hard tough silicious ore, which by careful mining can generally be kept in place ; but it sometimes falls in small quantities. Some fine sandy ore, mixed with the body of ore, is screened out in washing. Analysis :—Iron, 47.5 ; sulphur, trace ; phosphorus, 0.4 ; insoluble, 17.3.

On the southwest side of Lane's gap gangways follow the same bed ; the ore being of the same quality ; but the bed more irregular and contorted. The ore outcrop continues visible on the surface for some distance southwest of the gap ; but all the way along the ridge to Three Springs quantities of ferruginous sandstone blocks strew the ground; the ridge being much broken by ravines and often very low ; the sandstone forming a rough crest, and displaying *pulpit rocks* like castle walls.*

Sweeping around the south end of Jacks mountain, the Oriskany outcrop passes by Saltillo into Hare valley, and returns to the Juniata at Mapleton, where fine exhibitions of it are made at the foot of the mountain, and glass-sand mines have been successfully worked for many years ; these will be described directly.

The McVeytown southern outcrop of the Aughwick synclinal basin runs to the bend of the Juniata river three miles east of Mount Union. Along the Pennsylvania railroad the outcrop is broadened by two rolls, which make separate ridges, cut by the double ox-bow-bend of the river ; they then continue southward toward Orbisonia. Four anticlinal ridges of Oriskany project their ends southward in *echelon ;* coming to successive points ; the first opposite Mount Union ; the second opposite Aughwick mills ; the third at Shirleysburg ; and the fourth at Orbisonia. The Broad Top railroad keeps west of these outcrops, but touches the last three points. Between the *second* and *third* Aughwick creek makes it last three miles to the river. Be-

* The Corniferous shale over the Oriskany is here 75′ to 80′ thick and holds a good deal of ore which is scattered over the surface but is not worth mining.

tween the *third* and *fourth* lies Germany valley with its Fort run. Between the *fourth* and the foot of Black Log mountain heads up another little synclinal valley (of higher rocks) doubled by an intermediate roll, as shown in the Orbisonia section. But from Orbisonia south into Fulton county, past Fort Littleton, the outcrop runs straight for 20 miles.*

In the little basins pointing up between the *Oriskany* ridge the iron-ore deposits that are mined in the *Corniferous shales*† and in the *Marcellus* will be described hereafter; but openings have been also made in ore which lies *in the Oriskany sandstone itself*, or in the shales beneath it; as for instance opening 5 on Range 2 (F 120) where the Rockhill company work wash ore mixed with clay, very silicious, with a shaly fracture (being nothing more than decomposed ferruginous shale) from 6′ to 12′ thick; analysing:—iron, 33.2; phosphorus, 0.3; insoluble, 41.7. The shales under the Oriskany are here 100′ thick.

Sandy ridge continues for a few miles south from Orbisonia and then, owing to the increasing dip, passing into the foot slope of the mountain it forms a terrace into which Aughwick creek $\frac{3}{4}$ of a mile southwest of Meadow gap cuts. Further south the dip flattens again, and a low Oriskany ridge separates itself from the mountain, but keeps close to its foot. The Oriskany sandstone itself (dip 55 N. W.) contains a considerable amount of iron.‡

At Ramsey's, 5 miles from Fort Littleton, a large show of surface *Corniferous ore* exists (about the middle of the

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* The whole range of these ridges once went by the name of *Royer ridge;* but that name is now confined to the outcrop facing the valley; the back outcrops next to the mountain being called *Sandy ridge*. The topography can only be understood by consulting the colored geological map of Huntingdon county.

† Opening No. 6 (Hawk) works pots of ore in the Corniferous shale *above* the Oriskany; very silicious; merely highly ferruginous shale; the pieces of ore when broken showing a core of slate. Abandoned opening No. 8 is the same. At abandoned opening No. 15 a large quantity of the same has been mined and the surface northeast of No. 16 shows a good deal of the same.

‡ The overlying *Corniferous shales* are here 125′ to 140′ thick, ore being scattered in small quantities over the surface along the line.

Corniferous outcrop) some pieces weighing 15 or 20 pounds.* The surface show continues in a little valley as far as to the gap of the creek through the ridge. Here the *Oriskany sandstone* is solid, but only from 25′ to 40′ thick, dipping 48° N. W. A large quantity of blocks lie scattered along the western base of the ridge, some of them so ferruginous as to be mistaken for ore.

West of Fort Littleton and north of the Broad Top road the Oriskany ridge becomes several hundred feet high, the sandstone forming the crest and western slope; solid under cover, but weathering at the surface into small beds of sand.

The irregularities of the deposit in this region is seen on comparing measured sections; the *Oriskany sandstone* being 150′ at Orbisonia, and only 58′ thick at Three Springs six miles southwest of Orbisonia. Here the following section was carefully made.

Section at Three Springs in Huntingdon county.

Marcellus black slate	Upper member,	571′	875′
	Middle member,	20′	
	Lower member,	284′	
Oriskany Sandstone	Upper part, coarse grained ferruginous and calcareous sandstone (and ochre),	12′	58′
	Middle part, with friable sand with pebbles size of a pea,	15′	
	Lower part, coarse grained sandstone more friable, breaking irregularly, iron-stained surfaces, coated with red hematite, fossiliferous local ore bed near bottom,	31′	
Lower Helderberg	Upper part shaly,	30′	162′
	Lower part massive fossiliferous,	131′	
Water lime beds,			580′
Salina beds,			440′

There is no trace here of *Calciferous* or *Caudagalli* over the *Oriskany*. It is astonishing to find *less than 60′* intervening between the bottom of the *Marcellus black slate* and the top of No. VI limestones. It is a flagrant example of those infinite local irregularities which pervade our

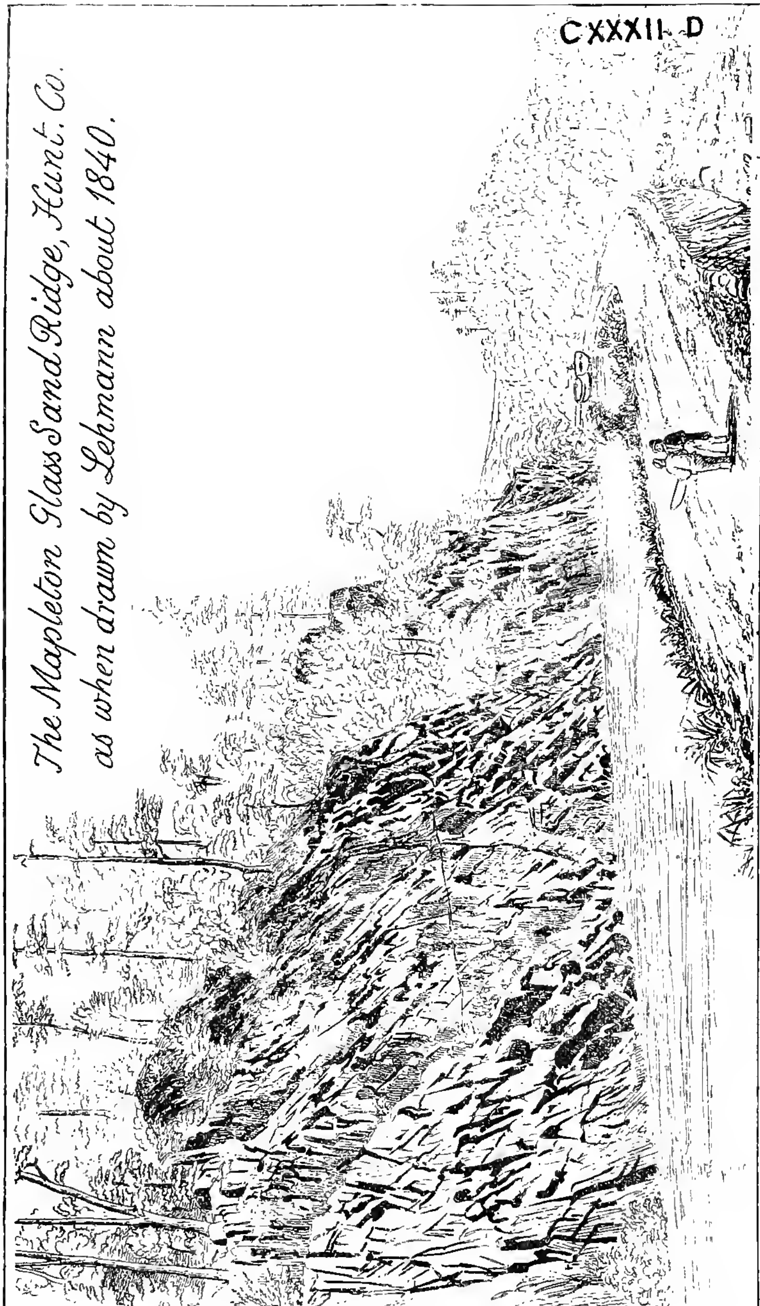
*The ore of the *Corniferous shales* is apparently rich, but does not seem to be in large quantities. The ore outcrop follows the base of the Oriskany ridge except where the flattened dip widens the valley and the ore crop runs across the flat.

geology and make a hard and fast systematic nomenclature impossible.

Fossils at Three Springs and Orbisonia.

At Three Springs the *upper* 12′ of the Oriskany consists of non-fossiliferous coarse ferruginous and calcareous sandstone, the top layers of which have been weathered into ochre. The *middle* 15′, is a less friable pea-conglomerate. The *lower* 31′, is the ordinary coarse friable sandstone, breaking into irregular shapes, and containing a good deal of iron. It is in this lower division that the numerous fossils lie; namely the large *Orthis hipparionyx;* a large *Rensselœria ovoides;* with *Rensselœria ovalis* and *Rensselœria marylandica; Spirifera arenosa*, and *Spirifera arrecta; Eatonia peculiaris; Mogambonia lamellosa*, and *Pterinea textilis; Platyceras ventricosum; Cyrtoceras expansus;* and the trilobite *Dalmania micrurus;* a combination which is perfectly characteristic of the Oriskany sandstone everwhere; a collection of animals wholly marine; no remains of fish, land plants or sea weeds.

The complete difference between this fauna and an equally abundant fauna collected at Orbisonia from the 50′ of No. VI limestone 100′ beneath the Oriskany, is very striking (the intermediate 100′ being comparatively non-fossiliferous), viz:—*Acervularia*, *Alveolites minima*, *Astylospongia inornata*, *Orthis oblata*, *Pentamerus galeatus*, *Rhynchonella formosa*, *Atrypa reticularis*, *Aulopora*, *Conophyllum*, *Merista arcuata*, *Merista lævis*, *Stromatopora*, *Trematospira formosa*, and *Zaphrentis;* not a single genus, except *Orthis*, being common to the two lists.



CXXXII D

The Mapleton Glass Sand Ridge, Hunt. Co.
as when drawn by Lehmann about 1840.

CHAPTER LXXX.

No. VII, Oriskany, on the Upper Juniata, in Huntingdon, Bedford, Blair, and Centre counties.

The Mapleton glass sand range.

Ths *Oriskany sandstone* makes a great show where the Juniata river bends from a south to an east course to enter Jack's Narrows. The railroad from Huntingdon descends the left bank along a sloping wall of Oriskany (65° to 79°, west) until it crosses to the right bank and sweeps round the bend through Mapleton, where, south of the village, a steep high ridge begins running S. S. W. up Hare valley. The outcrop crosses the river and rises in a bluff on the opposite mountain side, and runs on N. N. E. up Mill creek valley into Henderson, and through Barree into Jackson township, whence it returns to the Juniata river as Warriors Ridge.*

The *Mapleton Land Company's* first quarry is just west of the village, on the eastern face of Sand ridge, and therefore in the lower beds. The other, a furlong further south along the ridge, reaches the lower beds by a tunnel through the underlying shales †

The middle beds of Oriskany at the first quarry hold vast numbers of *Rensselæria ovoides*, *Grammysia* (*? sp.*) *Spirifera arrecta*, *Eatonia peculiaris* (*?*), *Platyceras tortuosum*, *P. conicum* (var. *inornatum* and var. *inflectum*),‡

* This chapter is chiefly compiled from Prof. White's Report T3, 1885; and Mr. F. Platt's Report T, 1881; as the foot-notes show.

† This is one of the few places where the exact base of the Oriskany can be seen; the tunnel passing instantly from fine clayey shales up into coarse sand rock; the shales being partially changed for several feet under the sandrock into clay, by drainage waters through the porous rock. The capacity of both works is estimated at 40 tons per day.

‡ Varieties proposed by E. W. Claypole, who identified the other shells in this list (T3, 119 and 274)—"Cow's horns," long curved sea-shells (*Platyceras*) are abundant in all these quarries, but most at Faust's, where some of the rock layers are honeycombed with casts of them in sand, the shell itself having been dissolved away.

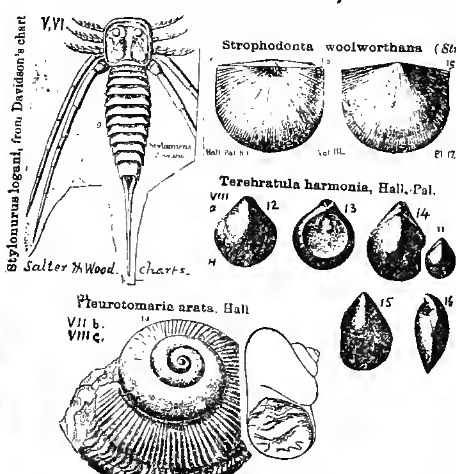
CXXXIIB

No. VII Pulpit rocks resemble Saxon Switzerland,

and those of the Columbia river & Colorado parks.

Pacific RR report Vol III.

Fossils of V, VI, VII b, VIII a, VIII c, omited from the page plates.



P. platystoma, and *Platystoma ventricosum*, mostly as casts, leaving the rock completely honeycombed. These fossils were all collected from below the middle of the formation, which is 150′ thick. *Spirifera arenosa*, which is not among them, was observed by White at other localities to be abundant at the top of the formation.

North of the river the face of the ridge is bared by a large abandoned quarry in the *upper beds*, which were found to be rather too hard.*

Faust's glass sand quarry is further along (north) in the *upper beds*, where the wall is nearly vertical, 150′ high. The rock is first burned, and then crushed dry ; very little water being used, and only for the refuse.

Matteer's glass sand works are a thousand paces further north, where a tiny brook breaks through the ridge; but water is pumped from the canal to wash the rock, quarried from the softer *lower beds;* capacity of works 30 to 35 tons per day, mostly shipped to Pittsburgh.

The Juniata Sand Company has a fine quarry in the *lower beds*, 150 rods north of Matteer's, and less than a mile south of Mill Creek village, where an ample brook breaks through the sandstone ridge between rock cliffs.† The Oriskany is here 125′ thick, but only the lowest 30′ of beds is now used, the purest and softest (i. e. the best leached) of the series. The top of the underlying 125′ of shales is converted into a bluish white clay.‡

The outcrop is well exposed for six miles ; and no doubt equally good quarries could be worked at many other points along the line. A gap in the ridge is not necessary. When the top coating is removed soft sand rock can be found almost anywhere, although parts of the formation

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* This is near the canal lock, a mile north of Mapleton.

† A steam crusher and washer prepared daily 35 tons (for Pittsburgh, Wheeling, Bellaire and other places) of second-class sand for bottles, fruit jars and certain grades of window glass. The brook not only washes but transports the washed sand down a small flume to the railroad.

‡ Under these are seen flaggy limestone (No. VI) 19′; *Stromatopora bed*, 8′; slaty impure limestone, visible 25′, in the little vale which separates the Sand ridge from Stone mountain

Indian Chief Rock near Williamsburg Blair Co. from Lehmann's picture, G.P. 1858.

CXXXII. E.

have partially escaped the action of percolating waters and remained harder than other parts, either because of original differences in the deposit, or because of differences in the groupings of the cleavage planes.

Opposite Decker's saw mill (4 m. N. N. E. of Mill Creek station) is a high cliff of Oriskany, and blocks lie strewed about.*

The Broad Top Huntingdon Synclinal.

The Oriskany descends almost vertically from its outcrop along Stone mountain to a calculated depth of 7100 feet beneath the river level at the mouth of Pike run in Henderson township; and then rises, northwestward, at the rate of 25°, flattening to 20°, 14°, 10°, and finally 5°, to the surface again at the Car Works at the upper end of Huntingdon borough, a mile above the railroad station.†

VII. Warrior's Ridge described.

Warrior's Ridge‡ is an unusually expansive outcrop of *Oriskany sandstone*, of crescentic or rather semi-circular shape, about 10 miles long by 4 miles wide, across which the Juniata river cuts a deep and narrow trench from Peters-

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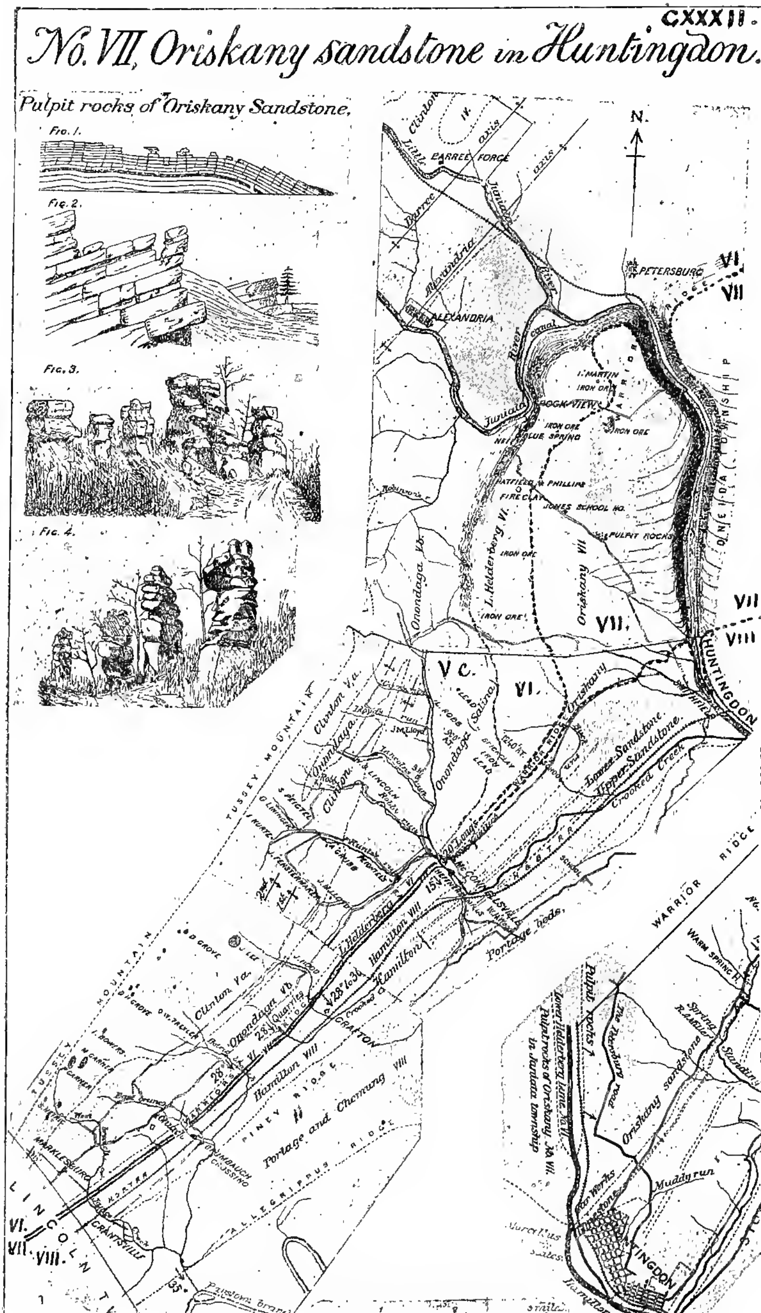
* In Barre township the outcrop is well exposed by a brook entering Stone creek just below its forks, at P. Wilson's saw mill, ¼ mile below Logan Co.'s saw mill; and by Henderson's brook, ½ mile further east.—The great bend of Stone creek takes place as soon as it gets through Warrior's ridge, and begins to scoop its channel in the Marcellus shales.—Two high synclinal spurs of Oriskany project into Jackson county.

† For 1500′ below Pike's run the river bank shows occasional Catskill red shales. The depth is made by 2620′ (IX) + 700′ (IX–VIII) + 2516′ (Chemung and Portage)+ 1260′ (Genessee, Hamilton and Marcellus(=7096′.) (T3, 265, 270). The Broad Top synclinal crosses the river about 500 yards below Pike's run, and 500 yards above the 198th miles post Pa. RR. The rise from the bottom of the synclinal to the appearance of the Oriskany at the Car Works is about 6 miles. Northward, along the axis of the synclinal, the Oriskany rises at the rate of say 5° and gets to the surface (on the Barree-Jackson township line) in eleven miles. Southward it sinks to a depth of more than two miles beneath the Broad Top coal field.

‡ The Indians gave it this name. They had their great council fire at the "Standing Stone" (now lost) on the flats of the creek at the lower end of Huntingdon. One piece of this famous monolith monument was built into the wall of a neighboring house. In France it would have been called a Menhir.


CXXXII.
No. VII, Oriskany sandstone in Huntingdon.
Pulpit rocks of Oriskany Sandstone.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
N.
PETERSBURG
ALEXANDRIA
BARREE FORGE
Juniata River
canal
ROCK VIEW
BLUE SPRING
HATFIELD & PHILLIPS FIRE CLAY
JONES SCHOOL HO.
PULPIT ROCKS
IRON ORE
L. Helderberg VI.
Oriskany VII
Onondaga Vb.
ONEIDA TOWNSHIP
HUNTINGDON
VI
VII
VIII
V C.
Clinton Va.
Onondaga Salina
Lower Sandstone
Upper Sandstone
Crooked Creek
TUSSEY MOUNTAIN
WARRIOR RIDGE
McCONNELLSVILLE
Portage beds
Hamilton VIII
GRAFTON
PINEY RIDGE
Portage and Chemung VIII
ALLEGRIPPUS RIDGE
MARKLESBURG
GRANTSVILLE
LINCOLN TW
Pulpit rocks
Lower Helderberg lime. No. VI.
Pulpit rocks of Oriskany No. VII. in Juniata township
Oriskany sandstone
Muddy run
Hamilton road
miles

burg to Huntingdon, exhibiting the internal structure of the ridge, or rather sloping plateau, the upper surface of which is made by the *Oriskany sandstone* formation (never less than 50′, and sometimes more than 100′ thick) supported by sandy shales (200′ to 250′ thick) and these by the Lower Helderberg (Lewistown, No. VI) limestone beds, which begin to rise from the river bed a mile or more above the Car Works, and are quarried in the upper end of the gorge. The rise of the rocks through the gorge is gentle and wavy, interrupted by stretches of flatness and by gentle reverse dips. These are the flat waves which broaden out on the ridge; and are the southwestern prolongation of the steep sided waves of the Seven Mountain country to the northeast. Where the waves enter the crescent from the northeast, the plateau is narrowed by successive offsets * to its eastern end, where it sends out synclinal spurs, and at last joins the Sand ridge outcrop in front of Stone mountain, as already described. Where the waves issue from the crescent southwestward, they become the rolls of the fossil ore-range back of McConnellstown and in front of Tussey mountain. At half-way between the Juniata and McConnellstown the plateau is reduced to a narrow low ridge, with steep (45°±) dip, which thenceforward runs in almost straight line (due southwest) 18 miles to the Bedford county line, and 40 miles further to the Maryland state line.†

No. VII. Pulpit Rocks.

Warrior's ridge around the northwestern sweep of the crescent rises 400′ above Shaver's creek (red shale) valley which it overlooks.‡ Its crest is the last outcrop of the

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* The first offset is 3 miles east of Petersburg, made by the northern Greenlee mountain anticlinal passing the mouth of Henry's run. The second is at the head of Gregory's run. The third at the northern corner of Oneida township, deeply indents the escarpment, making a pointed cove. The fourth is also a cove made by the Ennisville anticlinal.

† From McConnellstown to the Bedford line the H. & B. RR. runs at the southeastern foot of this ridge, but then leaves it, returning to it at Tatesville and following it to Everett.

‡ In some places in Porter township it attains a height of 1250′ above tide; P. RR. stations at Petersburg and Huntingdon being only 678′ and 622′ above tide.

Oriskany, worn into miles of *pulpit rocks*, isolated or grouped, the tallest of them projecting their tops above the woods which cover the ridge; the disintegrated sand being swept by rains over the steep slope below, and collected in local deposits at the mouths of the numerous shallow ravines which descend to the valley.

In some places the pulpit rocks are so numerous as to make "rock cities," isolated piles of rock 50′ high, with passage ways from one to ten feet wide between them.* One such just north of the turnpike to Alexandria, about 3 miles from the Huntingdon bridge, called "The Pulpit Rocks" par excellence, is about a mile back from the river. At some places along this road (probably on the axes of rolls) the whole formation has been removed, and the underlying shales make the present surface. †

The cornice of rock which crowns each side wall of the river gorge, is in like manner broken by erosion into *pulpit rocks*, which tower high above the railroad along the left bank; and along the turnpike which runs over the ridge back from its right bank. These last are in fact the last remnants of the formation, or of its softer upper beds,‡ where they have been in great measure removed from over the lower harder beds, or where these also have been stripped from the upper surface of the underlying shales. (See wood cuts, T, p, 216.)

They look like rounded blocks of rock artificially piled up into columns; but the planes of division between the horizontal strata correspond in each group of columns, showing that they were once connected. The process of erosion has been made easy by two sets of vertical planes which cross each other at right angles, cutting up the whole formation

* *Wolf Rocks*, near A. P. Wilson's in Walker township is such (T 3, 209).

† "Rock View," where the Juniata cuts into the face of Warrior ridge, and makes a vertical precipice of 400′, looks from below like the cliff edge of the Oriskany; but it is not. The whole precipice is of No. VI limestone piled on Salina strata; not only the Oriskany but the shales having been eroded; the nearest edge of Oriskany being a mile distant, to the east.

‡ On the Sand ridge outcrop, north from Mapleton, we have seen that the upper beds are harder than the lower; which only illustrates the incessant local variability of this and every other geological formation.

into more or less cubical blocks, and flat square slabs, all the angles and edges of which are rounded by decay.*

The upper portion of the Oriskany formation in the fantastic cliff ledges of the river gorge is a yellowish white sandstone charged with many casts; *Spirifera arenosa*, *S. cumberlandiæ*, *Rensellæria ovalis*, and *a Platyceras* being especially numerous. The lower half of the formation is made up of beds of white, fine grained, excessively hard, and *almost non fossiliferous* sandstone, extensively quarried for *railroad ballast*, just above the car works, where they make their first rise in the cliff.

The Oriskany is overlaid at Huntingdon by only 10′ of gray (caudagalli ?) shale, over which *Corniferous* greenish-gray limestone beds appear.†

The Oriskany in Warrior's ridge is often a pebbly coarse sandstone; and it has limy streaks in it, owing to the vast number of fossil shells which lie in colonies or banks.

No glass-sand quarries are opened in the Warrior ridge; perhaps because the horizontal attitude of the formation has permitted the drainage to descend easily and rapidly *across it* by the cleavage planes, instead of slowly *along it* by the bed planes as in Sand ridge. Warrior's ridge has therefore not been so thoroughly leached of its lime and especially of its iron.‡

At McConnellsville, the *Oriskany sandstone* is 50′ thick,

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* The difference in solidity of the different strata is measured by different degrees of decay; some blocks overhanging those by which they are supported; each column falling at last, in the lapse of ages, by the more rapid destruction of its lower blocks, which then become heaps of sand, while the harder blocks remain to encumber the surface.

† These are seen near Huntingdon, just east of the Old Petersburg road crossing the road to Warm Springs; and again on the latter road a quarter of a mile further east. The outcrop of Oriskany keeps just south of this road for a mile and a half, crossing to the north of the road at R. A. Miller's. The "Warm Springs" (which are not warm) issue from the Sandstone, and have no medicinal quality. Half a mile N. E. of the springs the Oriskany is exposed along Stone creek, dipping 15° (S. E.) into the water, its top layers *full of fossil casts*: and so again from McDevitt's continuously N. E. into Barree township.

‡ In the overlying shales, at Huntingdon, are a few thin layers of lean *carbonate of iron ore*.

dipping 20° (S. E.), over shales, 200′, which make the crest and part of the S. E. slope of the ridge (T3, 200).*

In Lincoln, the ridge is broken through eight times; first by the head of south branch of James creek; and then by seven branches of Coffee run.

Coffee run section (T3, 169).

Hamilton, upper, middle and lower (calculated),			733′
Marcellus	shales, partly concealed,	250′	550′
	black slate (dip 40°),	300′	
Corniferous limestones and lime shales,		35′	75′
	concealed,	40′	
Oriskany Sandstone,†		(estimated)	60′
	shales,		200′
No. VI limestones, etc., and concealed,			378′
Salina limestones, green shales, red shales,			1150′

In Hopewell, the ridge is gapped by the three branches of Shy Beaver creek, and its crest runs 300′ or 400′ above the water in the main gap. The Oriskany outcrop is too much weathered to measure, but is estimated at nearly 75′, the contact with the underlying shales being concealed.

At Cove Station, on the Bedford county line, is a gap in the walls of which the sandstone is much weathered, but becomes massive (65′ thick) and the ridge high a few hun-

*The sandstone follows the turnpike closely nearly to the river, into which it sinks nearly opposite the mouth of Bryan's run, having sloped gently down from the summit of the ridge. Along the turnpike just above the Penitentiary can be seen the top of the Oriskany; over it 20′ dark shales, partly seen; limestones, etc., 10′; black slate, 40′; limestone, etc., 12′; and over these the main body of Marcellus dark shale. The valley of Crooked creek conceals about 550′ of overlying strata.—South of the McConnellsville gap the ridge is unbroken for three miles. In Penn township it is gapped six times; at Grafton by Hood's brook, and then by the extreme head brook of Crooked creek; then by Hetric's branch; the east branch at Brumbaugh's crossing; by another branch at Trexler's quarry; lastly by the main branch of James creek at Grantsville.—*At Grafton* the dip is 30°, S. E.: sandstone 50′, underlying shales 225′.—*At Trexler's gap*, now known as the Patterson's lands, the name given to White's section in T3, p. 183, isolated patches of the sandstone occupy the southeast slope of the ridge; dip 28°.—*At Hetric's gap* the dip is the same.—*At Brumbaugh's* crossing appear (going N. W. from RR.) *Marcellus*, visible 75′; *Corniferous* limes and shales 75′; *Oriskany* 50′; shales 200′; No. VI limestone and Salina 750′; down to the turnpike. Here the *Corniferous* makes a long ridge, easily followed.

†It is not exposed in cliffs on Coffee run; but large blocks of it are scattered over the S. E. slope of the ridge.

dred yards to the northeast and southeast. It is covered by dark lime shales (topped by a few thin greenish poor limestone layers) 55′; then gray shaly limestone and dark shales, with Hamilton fossils, 25′; then *Marcellus* black shale 300′, etc. upwards (T3, 156).

Across Bedford county, *Warrior ridge* runs nearly straight through Liberty into Hopewell township 10 miles to Yellow creek. In Liberty it is merely a range of low knobs gapped four times in three miles by brooks which enter the river near Saxton; twice by Raver's run branches, and again a mile from Yellow creek.* From Yellow creek to the river at Everett, 9 miles, it is gapped only by Piper's run, and at Tatesville.† From Everett onwards to the gap at the head of Clear creek (6),‡ thence to the gap of Sweet Root creek (8½),§ thence to McLewees' gap (5),‖ and to the

* From Cypher school house near the county line to the Reformed church (4 miles) frequent exposures show that the *Oriskany* is soft and so much eroded, owing to its nearly vertical dip, that Warrior's ridge disappears for distances and that the sandstone is immediately overlaid by 150′ of alternate thin limestone beds with black shale partings (as described under the head of *Corniferous* in a following chapter), the ordinary gray shales being absent, and therefore no trace of the *Caudagalli grit;* for the shales are as black at the bottom as the top (T2, pp. 199, 233).—At Wiemer's gap the dip is 65° (S. E.). At Bolleger's gap 80°.

† In John's run gap at Tatesville, the Oriskany is well exposed along the railroad, its part soft, its upper layers solid, massive, coarse grained and more or less *conglomeratic*, making the crest of the ridge. All the way to Everett along the road it is seldom seen in place. Near Barndoller's tannery the black shale is seen resting on the sandstone, and carrying a narrow yellow streak of ferruginous shale.

‡ At Barndoller & Bachman's, a mile south of the river, *brown hematite ore* pits at the top of the Oriskany yielded some 53 per cent ore (T2, 217). Further up Clear creek the dip has become 55° (S. E.) and therefore the ridge grows higher.

§ At the gap at O'Neill's mill, a bold wall of of Oriskany on the east side of the road shows it greyish white, massive, coarse grained, *with pockets of conglomerate;* it outcrops high on the ridge and to the crest, where No. VI limestones are exposed. *Iron ore* overlies it in several places, but how much is not known (T2, 208). At Sweetroot gap, opposite Chenyville, the Oriskany shows poorly on the hill slope; but shows in the gap, much of it *snow white*. Brown hematite ore is also common at its top, but all the old pits are fallen in (T2, 204).

‖ At McLewees' gap the dip is only 30° (S. E.) and this accounts for the uncommon height of Warrior's ridge as it approaches Maryland; but it is much more poorly shown than in McLewees' gap (T2, 204).

gap at the state line ($2\frac{1}{2}$,=22 miles in all) it is a bolder ridge, faced and roughened on its S. E. slope by the Oriskany sandstone, and rocky layers in the underlying shales; while from its N. W. slope issue the limestone outcrops of No. VI. Approaching the state line it becomes really mountainous, owing to the increasing thickness of the sand mass, and a corresponding increase of the whole underlying limestone mass of No. VI.

No. VII in Southern Bedford county.

Sinking eastward from its Warrior Ridge outcrop the Oriskany lies concealed under the eastern third of Bedford and nearly the whole of Fulton, so that its character is unknown.

Westward from the Warrior Ridge outcrop it descends from the Tussey mountain arch to make the synclinal crest of Martin's Ridge in Bean's Cove, the crest itself being of No. VI limestone, beneath which appears the collapsed and overturned double outcrop of VII on the west slope. Its next descent is $2\frac{1}{2}$ miles further west, to make Knobbly mountain in the Evitt's creek (Cumberland) valley.*

* In Cumberland valley, at the state line Knobbly mountain is made by No. VI and Oriskany, with a top of Marcellus. The synclinal is doubled by a middle roll; the main synclinal, receiving a short synclinal as its companion on the eastern side; the creek flowing between them along the anticlinal roll in the limestones; leaving the little synclinal on its left bank ending in a north point of Oriskany six miles from the state line. The creek crosses and recrosses the synclinal; and its side brooks cut up the synclinal ridge into a great number of isolated hills of Oriskany; hence the name of *Knobbly mountain:* but these knobs are bold, rising from 300′ to 500′ above the side valleys. Most of them are wind gaps; but Evitt's creek cuts through the ridge to its base, five miles north of Centreville; again at Centreville; and three of its western branches make as many deep water gaps between Centreville and the State line. Exposures are rarely good in the gaps and the Oriskany is seen along the hill tops chiefly as blocks upon the surface. The gap road from Bethel church ($2\frac{1}{2}$ miles from the state line) to Growden's mill on Evitt's creek, shows the Oriskany (at Deffibaugh's spring) dipping 55° (E.) and coming up again with a steep west dip near the Methodist church, the center line of the basin being say 800′ west of the church. The creek flows in the anticlinal, and the Oriskany dips east from it, being exposed from Growden's mill northward, until two miles from Zembower's mill; a mile further it narrows to a point. For some miles before reaching the Bedford township line Schober's creek and the road mark the eastern outcrop (base of Marcellus) leaving the western outcrop to

Its next descent westward, after passing the Will's mountain anticlinal, is as the fine vertical outcrop along Wills' creek, extending 16 miles from the state line northward past Hindman and Fossilville to Buffalo Mills; thence 7 miles along Buffalo creek to Stukeyville; 5 miles to Cessna; 3 miles to St. Clairsville; zigzaging 7 miles to the Blair county line.*

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make *Knobbly mountain.* Great blocks of Oriskany *full of fossil casts* have rolled down to the road north of Arnold's saw mill; but specimens cannot be obtained from the crumbling sandstone. South of Bedford Springs the obscure eastern outcrop would seem to pass close to the hotel; but the western outcrop is well exhibited at several places south of the Springs, and always highly fossiliferous (as described in the text). This long double line of Knobbly mountain's outcrop extends from the state line (where it is a mile wide for six miles, and then about half a mile) 21 miles, to its northern end at Bedford Springs, where the little basin is spooned into the air by a number of rolls which cross the Juniata river in Bedford town. Its last appearance is on the hill top south of the Avondale hotel. The oval outcrop in the Bedford basin north of the river is an enlargement of Knobbly mountain isolated from it by erosion; enclosed by a broad circular valley of VI and V, and enclosing a ring of Marcellus and Hamilton hills and a central patch of Portage and Chemung, No. VIII; Dunning's (Evitt's) mountain ot IV surrounding and overlooking it on the north and east; Dunning's creek cutting a deep trench into it from the west at Hughes' and out of it at its southern end. The road from Bedford along Evitt's mountain reaches the VII outcrop (dip 40° N. W.,) at the forks just beyond I. Shaffer's house. A road leaving the Bedford-St. Clairsville pike just north of the cemetery reaches it just beyond W. Felter's, and keeps just east of it (in Marcellus shale) to the creek, where it shows at Hughes' house. Here *Oriskany iron ore* (brown hematite) has formerly heen mined in a small way (T2, 155). Hence northward for three miles the outcrop (dip 15° S. E.) runs to a point on the Imlertown road marked by fragments; and then returns south by the Evangelical church, Bailey's mill, Stiffler's, Beegle's, the Lutheran church, Lingenfelter's (dip 8° W.) to the Race ground by the Chalybeate Spring. At the Evangelical church *the Marcellus black shale may be seen resting on the Oriskany sandstone.*

* Along Wills' creek, at the state line, the *Oriskany* has shared in the erosion of the *Marcellus* (VIII), but rises from the bottom land into a lofty conical hill in Maryland (T2,95), east of the creek, separated from Wills' mountains by a deep vale of *Clinton shales* (V). Going north up the creek VII occasionally appears at the west edge of the bottoms; from school house No. 1 to S. H. No. 2, it is exposed on county road, and in railroad cuts, as a calcareous grit, blue or *reddish blue,* not easily weathering, but *crowded with fossils,* which are dissolved out, or reduced to powder, leaving tender casts in the honeycombed, soft, crumbling, iron-red sandstone.

A long pointed loop of *Oriskany* enclosing an *anticlinal* prong of No. VI limestone, points south to within a mile of the state line. The corresponding *synclinal* prong of *Marcellus* points north to Palo Alto (4 miles from

These long outcrops of the *Oriskany* in Bedford county, together with an oval outcrop around a *synclinal* dimple 7 miles long by 3 wide north of Bedford, and another oval outcrop 11 miles long, by 2½ wide made by the *Chestnut ridge anticlinal* at Shellsburg, 8 m. W. of Bedford show its character between Warriors' Ridge and the Allegheny mountain, beneath which it plunges to a depth of 11,000 feet, and thins away to nothing westward in Ohio and northward in the Lake Erie region.*

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state line); dips 20° (E.) and 55° (W.). The synclinal is here only 350′ wide, its east dip 90°. The synclinal of VII points out on the hill top S. E. of J. Cook's house. Half a mile west of Palo Alto, on Gladden's run, dips 15° W. in a bluff 110′ high. Near J. Wilhelm's, top beds very *ferruginous*, with *excellently preserved fossils*. S. of S. Close's, dips 70° to 50° W., with a sharp pinch at the summitof the fold. Near Hyndman, dips 85° W., diminishing to 55°. Well exposed behind Evans', dip 20°, east.

The Hyndman section is given in the text. Ascending Little Wills creek by the county road VII is well exposed on the hill side descending to Wills creek RR. station; hence to Fossilville exposures rare, outcrop under the bottom land. A mile north of Fossilville VII dips 80° (E.). *This is an overturned dip*, for VI lies against its east side and at Wolford's lime quarry stands vertical (90°).

At Bard station VII underlies the railroad; northward (up creek) creek bottoms; VII appears at Buffalo Mills, and is occasionally exposed for the next 6 miles, past Sulphur Springs to Man's Choice station. At Stuckeyville VII is buried under the bottoms, but makes a low ridge southward; dip 75° (N. W). Two miles north of Stuckeyville (at Semler's), VII is concealed, but VI dips 60° (W.).

At Cessna the Oriskany dips nearly 90° (W.) in a narrow ridge which extends from Dunning's creek, past St. Clairville six miles, north to a synclinal point, between Pine ridge on the west and Dunning's mountain on the east. It then returns southwest, 2 miles, to the forks of Bobbs and Scrubgrass creeks and makes an anticlinal point. Then resumes its northerly course into Blair county. The sandstone shows on the township line east of the Bobb's creek bridge, on the Pine Ridge anticlinal.

At Ake's mill, Hull's lime quarry (VI) dips 60° (S. E.); just west of it the dip changes to N.W. Large masses of Oriskany lie in the field and on the lower slope of the mountain, but no outcrop appears along the pike to Hollidaysburg. On the cross road to Imler's, the Oriskany dips from the west side of Pine Ridge westward almost flat. It contains in one exposure *Spirefer arenosa*; *S. arrecta*; *Megambonia*; *Eatonia peculiaris*; and *Merista lata*.

*The *Oriskany* top layers pass through the west end of Shellsburg borough, on the Bedford-Pittsburgh pike, in Napier township; dipping gently southeast from the southward dying *Chestnut hill anticlinal*; and running southwest past Calvin's mill, to the south point of its oval outcrop at the Juniata township line. They here return and run N. 10° E. in a

At Bedford Springs the Oriskany can be studied along the western side of *Knobbly mountain* at several exposures, all richly fossiliferous; the upper beds gray, weathering a lighter gray, stained with brown. The following fossils are very abundant but not well preserved: *Spirifera arenosa; S. arrecta*; *S. cumberlandiæ; Merista lata; Streptorhynchus hipparionyx; Platystoma ventricosum*, and a *Megambonia*, and *Platyceras*.

The Hyndman section of No. VII.

At Hyndman in the southwest corner of Bedford county, seven miles from the Maryland line, where the two railroads from Pittsburgh and from Huntingdon meet and descend Wills creek to Cumberland, the *Oriskany upper beds* of soft coarse, some of them conglomeritic, sandstone are ill exposed along the railroad, but better on the county road close by, dipping say 15° (S. E.), ... 40′

Bluish grit, with a few fossils, ... 6′

Sand beds, mostly grit like, very hard, blue to gray; some layers pebbly; fossils numerous throughout, but especially numerous in several thin layers; the most common being:—*Spirifera arenosa; S. arrecta; Rensselæria ovalis; R. suessana*; *Strophomena magnifica*, . . 30′

Sandstone beds, fine grained, gray, weathering easily to a soft state; fossiliferous; dipping 82° (N. W.), . . . 8′

Grit beds, hard, weathering jaspery; with *Strophomena magnifica*, ... 10′

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straight line 6 miles to New Paris; keep on down Dunning's creek 5½ miles to the north point of the oval to within half a mile of the junction of Dunning's and Georges creeks; then turn back and run S. 10° W. past Spring Meadow and Spring Hope, 9 miles to Schellsburg. The dips are so gentle that both ends of the oval are very much spread out. From Calvin's mill to Hughes' distillery the road runs over nearly flat Oriskany 1½ miles. The road from Schellsburg N. W. runs on Oriskany 2 miles and just touches the south point of the inner oval of No. VI which makes Chestnut ridge. At New Paris the dip is 35° westward. At J. A. Blackburn's and Spring Hope, in the Hogback ridge of Oriskany, the dip is 15° eastward.—The immense spring at Spring Hope comes from cavernous limestone beds of Chestnut ridge, but through the cleavage planes and loose disintegrated sands of VII. The dip of VII where Six Roads-Spring Meadow road crosses Dunning creek is 25° (W.). At Spring Meadow the dip is 18° (E.).—Fragments of No. VII brown hematite ore of VII occur at T. S. Holsinger's on the west side of the ridge.

Grit beds, blue, ... 10′

Sandstone (involved in a small fold of the strata) fine grained, dark blue; including ferruginous layers weathering rapidly; richly fossiliferous with *Spirifera arenosa; Rensselæria ovalis; R. suessana; Streptorhynchus hipparionyx; Eatonia singularis; Leptocoelia flabellites;* and other forms; *fucoid* markings on some layers; *Platystoma ventricosum*, and a *Platyceras*, in one layer lying 28 feet from the top, ... 34′

Cherty siliceous limestone (the cherty part beginning at 3 feet from the top); upper part containing *Spirifera arenosa; Platyceras; Favosites helderbergiæ; therefore a passage formation from VII down to VI;* well exposed where the cliff turns eastward at the railroad bridge.

No. VI blue limestone, etc., ... 20′

The total thickness of *Oriskany sandstone* is here 138′, and of rocks holding characteristic *Oriskany* fossils, 158′; whereas the total thickness in northern Bedford county is about 90′.—The calcareous nature of many of these beds is noteworthy, here; and still more so at Cumberland on the Potomac river.—The lowest or *transition* sub-division is exceedingly *cherty;* its *whitened fragments* occur abundantly on every Oriskany ridge in Bedford county; and its outcrops can be followed by them through Maryland into Virginia.

No. VII, Oriskany in Blair county.

In Blair county there is but one outcrop of the Oriskany formation, No. VII, running along the west foot of Dunning's mountain, from Bedford county northeast to Frankstown in a nearly straight line; then returning and sweeping round Hollidaysburg on the south to Duncanville; and then resuming its northeast course down the Little Juniata, past Altoona to Tyrone city, and the Centre county line. The length of outcrop is 60 miles, but from the Bedford to the Huntingdon line only 30 miles.

The formation is too thin to make a bold definite ridge, even supported as it is by the limestone beds of No. VI, and although what there is of it consists of massive, coarse grained, and sometimes conglomeritic sandstone beds. Its erosion is also assisted by its very steep westerly dip in most parts of its course, except when it is bent over the Hollidaysburg and Frankstown anticlinals, and in its circuit of the cove. Consequently while it frequently appears at the surface it is almost impossible to find a chance to measure it.

At Altoona a bore hole went down through 400′ of slate, 30′ of sandstone, 313′ limestone, 373′ slate, 890′ limestone.* Carefully measured dips of 50° and 52° at the well would make the actual thicknesses :—†

Marcellus and Corniferous slate (VIII); thickness,			250′
Oriskany sandstone (VII),			20′
Lower Helderberg	limestone,	192′	980′
	slate,	231′	
	limestone,	557′	

* Under the direction of Mr. T. N. Ely, Supt. Motive Power, Pa. RR., and stopping at 2006′ without getting water.

† The engineers drew their diagram for me on a dip of 41° (perhaps for reason) which would make the thicknesses 300′, 22′, 234 , 279′, 670′=1505′ ; instead of 1250′, as in the text. The well is at the railroad in the yards ; the outcrop of VII to the southeast of it, on the map, has dips of 50° and 70° ; those of the underlying limestone, 20° and 30°. A mile further northeast, VII seems to dip 45° (S. E. overturned ?). Two miles still further northeast at Baker's ore mine, VII makes a great show, but is so broken that its dip cannot be obtained ; the limestone beds seem to dip 54° and 50° (S. E. overturned ?) Midway between these two, the top beds of VI dip 43° (S. E.) and the bottom beds 38° (S. E. overturned ?) The topography of the mountain shows great disturbance and makes the overthrow probable (see index map in atlas to Blair county report T), but the structure is obscure. A long synclinal horn curves gently from the reservoir (S. of Hollidaysburg) northeast to Frankstown ; with two side outcrops of VII meeting in a synclinal point which is overturned, so that the southeast outcrop, which dips 75 (N. W) at the north corner of the reservoir, dips 80° (S. E. overturned) in Frankstown. The west outcrop of the cove comes close to this point and dips 30° (S. E.) cross section C in the Atlas shows this curious pinch in the Oriskany and its atitude underground in the cove.—At the south end of the Cove VII dips 40° (S. E.) ; on the east side of the cove 50° (N. W.)—At McKee's gap in Dunning mountain VII descends vertically. Further south opposite Bloomfield mines, it shares in the general overturn of all the formations in Dunnings mountain. It is evident that at Altoona the *Oriskany sandstone* is only 20′ thick, and that no slates underlie it unless the borers mistook lime shales for limestone in examining the drillings. But at Kimberlin's, 1½ miles north of Cause creek, a quarry of excellent firm *building stone* exhibits 30′ of beds. Near Allegheny furnace, two miles south of Altoona, and 200 yards north of Baker's limestone quarry beds of massive hard Oriskany sandstone measure in all 50′; underneath which lie 28′ of *dark lime shales*, and then the limestone. (See Baker's quarry section, T, 129.)

Glass sand.—In many places in Blair county the *Oriskany* is flinty; but usually, it is a friable sandstone, very much decomposed into sand along its outcrop. For instance, on the Poorhouse farm, a mile northwest of Hollidaysburg, a fine deposit of *clean sharp glass sand* is dug for foundry purposes. Overlying the limestone outcrop of VI it evidently represents the destroyed outcrop of VII.

Oriskany iron ore shows at only one place in Blair county, viz: on the wagon road 1½ miles northeast of Frankstown, where a bed of compact red ore 2′ to 3′ thick lies directly on the sandstone. (T, 35.)

A mile south of Tyrone city, at Bridge No. 12 of the Penn. RR. there is a cutting in Oriskany sandstone; and the outcrop makes the crest of the little ridge which runs past the west side of the town; * but it is soon buried beneath the bottoms of Little Bald Eagle creek, and nothing is seen of it as the valley ascends northeastward to the Centre county line.

No. VII, Oriskany in Centre county.

In Centre county, the *Oriskany* outcrop is concealed beneath the bottoms of Bald Eagle creek, past Hannah (2 miles), Port Matilda (5), Martha (8), to J. B. Mattern's farm, where it suddenly rises in a precipitous cliff along the southeast side of a short wooded ridge (40 rods long), around which the creek bends. Here beds of *calciferous sandstone full of Oriskany fossils*, dipping 20° (N. W.), indicate a thickness of 60′ or 70.′†

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* The *Caudagalli* grit may be supposed to exist here; for a large rock, rolled from the ridge, lay for several years on the flat north of the town, the surfaces of which were entirely covered with the *Cocktail fucoid*. The expense of securing this superb specimen would have been considerable. It may have been destroyed.

† In Taylor and Worth townships the bottoms are made of a mixture of shale and limestone clay. The mountain slope and foot is covered with a vast outspread of blocks of all sizes from the Medina crest; the vertical plunge of the measures making the slope short and steep and the *Clinton*, *Salina*, *Lower Helderburg* and *Marcellus* outcrops narrow. The Marcellus, where exposed continuously for a quarter of a mile in the ballast diggings, just west of Port Matilda, dip 50°, 52°, 48°, 45° (N. W.). Some of the layers are calcareous and represent the *Corniferous*. The *Oriskany* is nowhere viaible and probably does not exist. In Huston township between Mud

From this northeastward the outcrop is again buried, past Juliana (13 miles), Alexander quarries (15), Unionville (17), to within a mile of Milesburg* (in all 22 miles); here it reappears and remains visible for the most part past Curtin's (Old Eagle, 25). Howard (30); Eagleville (35); to Beech Creek (36 miles) where it enters Clinton county.

At the Alexander quarries a sharp synclinal roll of *Oriskany* is caught in the mountain slope.† Half way up the terrace, 120′ above the creek, beds of hard sandy limestone quarried for lime, dip 45° (S. E. into the mountain); and at the top of the terrace, 250′ above the creek, the same beds are quarried, dipping 90° (N. W.). Some not quarried are merely beds of coarse sand loosely cemented by carbonate of lime which a little acid readily dissolves leaving only the loose grains of sand. At both quarries *Oriskany* fossils can be collected; from the lower one were got *Spirifera arenosa; S. arrecta; Rensselœria ovoides; R. suessana; Merista lata; Orthis musculosa (?); Strophomena.* ‡

Lick and Juliana they dip 40° and 46° (N. W.) but from Laurel run to the Union township lines 32°, 25°, 28° (N. W.) No *Oriskany* appears. In Union, they are finely exposed in similar bluffs over the road, dipping 48°, 40°, 35° (N. W.) to Dicks run, 40°, 38°, 40°, 50° to the Boggs township line; but no Oriskany.

* The first appearance of No. VII is in the knoll at the railroad. At Milesburg its *fossiliferous* beds appear under the Bellefonte railroad bridge. Dipping 42° (N. W.). They makes a low ridge on the S. E. side of the creek *westward*, cross to the north side and end ½ mile from Snowshoe junction dipping then 35° (N. W.). The *clay* made by a mixture of *Oriskany* and *Marcellus* is used for bricks. *Eastward*, a knob of Oriskany north of the road beyond the old mill is *quarried extensively for glass sand.* Near Curtin's it is exposed in a small hill as a *ferriferous coarse sand rock*, with casts of fossils.

† This little basin is very interesting as a perfectly plain indication and illustration of the crumpling which took place on the steep northwest side of the Great Nittany valley anticlinal; and it helps to explain the dip of 74° (S. E.) in the Unionville limestone quarries (although that may be merely an overthrow dip) and the dip of 55° to 80° (S. E.) 2000′ northwest of the village of Howard. Over and quite near to the beds of the lower quarry, lime shales hold casts of an *Orthis* and *Strophomena* and a *Discina* (all too indistinct for *specific* determination) and seem to represent the upper part of the Oriskany formation. The little basin is only 20′ wide, but is deep enough to take in nearly 100′ of *Corniferous limeshales* and perhaps some *Marcellus.*

* See Prof. A. L. Ewing's report in T4, p. 431. The specimens are in the State College Museum.

East of Milesburg is a *glass-sand quarry*. East of Curtin's iron works are two *quarries for hearthstones* (for Pleasant furnace) 1,000 yards apart, excellent white sandstone with fossil casts, a little iron-stained, dipping in the western quarry 44°, in the other 50° to 60° (N. W.); the total thickness of beds exposed being about 75′.

From this onward the limestone outcrop broadens as the dip diminishes and makes the creek bottom land. Along its edge runs a high ridge of *Oriskany sandstone* as far as to the flats at *Howards ;* across which the outcrop can be traced by a heavy deposit of white and buff colored sand.* As far as Butler's run the ridge has a flat top 300 yards wide and shows no rocks in place, but east of the run trenches have been made at intervals for 700 yards all of them in good pure sharp *glass-sand* to depths of 10′ to 30′.† Dip. 20° to 30° (N. W.); east of Canoe run the the rocks dip 28° (N. W.).

The sandstone beds all along this ridge are a mass of fossil shells, mostly casts, helping to disintegrate the rock into sand. On the highland at the Liberty line, trial shafts for *Oriskany ore* go down 70′ and more before they strike limestone. Thin seams of a sandy brown hematite are passed through, and the sandrock is discolored ; but there is no sufficient quantity of the iron ore; only enough to have caused the abandonment of the Leather glass sand quarries. Large *fossil casts* are abundant. The maximum thickness of the Oriskany does not exceed 130′.‡

In Liberty township the southeast base of the low Oriskany ridge is washed by Bald Eagle creek. Its broad flat top is a deep bed of sand; huge bowlders of the rock, crowded with unusually large and beautiful *fossil casts*, cover the flats of Marsh creek. The junction of VII and

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* *At Howard* there is a basin ; thin ledges of No. VI limestone dipping 30° (N. W.); 70′ distant, north, a thin ledge of calcareous sandstone dipping 60° (N.); and along the old canal, $\frac{3}{8}$ mile N. W. of the village, a sandstone ridge dipping 55° to 80° (S. E.); the interval filled with Marcellus ? shale; but no Oriskany fossils seen. (Ewing, T, 431–2.)

† The largest pit was made on J. B Leather's land, for the Bellefonte glass works.

‡ Mr. Schenk's ore trial shafts in Liberty township went down in sand and sandstone 80′ to 100′ before striking limestone.

VI is plainly shown at Crider's lime quarry, exposing 45′ of beds, dipping 26° (N. N. W.); and at *Shank's* quarry (100 yards further west) where 40′ are exposed, dipping 22°.*

Across Clinton county the *Oriskany outcrop* can be traced four miles east from Beech creek along the low ridge bordering the Bald Eagle creek flats on the north until the creek makes its great bend in the *Marcellus* two miles west of the Susquehanna river. The line of outcrop ought to cross the river half a mile above the north end of the Lock Haven bridge, and run thence 10 miles (E. N. E.) through Woodward, Dunstable and Pine Creek township, to Pine creek two miles above its mouth. But not a trace of Oriskany is to be seen; although the *Corniferous limestones* with *Marcellus* black slate *above* them and 177′ of black slate *below* them are exposed along the river opposite Lock Haven and below Lockport, on top of the waved and faulted *Lower Helderberg limestones*, No. VI. Nor does it appear on Pine creek where the beds of No. VI are vertical. (See section, page plate, G4, 53.)

No. VII in Lycoming county.

In Lycoming county the *Oriskany* makes no appearance along the northern edge of the broad *Lower Helderberg limestone* outcrop (No. VI) which the Susquehanna river crosses and recrosses six times in the twelve miles between Jersey Shore and Williamsport. But five years ago small discoveries of Oriskany sandstone were made along the Williamsport and Muncy line, which prove the existence of the formation here and there under Lycoming as in Union county.†

*5,000 bushels of burnt farmer's and plasterer's lime per annum. (See sections on page plate T, 296.)

Oriskany sandstone,	12′	. . . .	15′
Gray slate,	2′	Impure fossil lime,	6′
Blue quarry limestane,	12′	. . . .	12′
Slate,	4′	Slate and shale,	2′
Shaly limestone,	8′		
Blue silic. limestone,	4′	with red chert bands,	5′

† Pennsville, Muncy township, blocks of Oriskany follow a terrace running along the lower slope of the hill at the north side of the village; the upper slope being Marcellus. The Friends meeting house at one end and

the school house at the other end of the village are built on the outcrop, the former partly from an old neighboring quarry in it. The geol. map in G, 2, omits it, and makes the Marcellus spread a few hundred feet too far south. The outcrop may be seen on W. Elliott's lawn, pointing up over the Bald Eagle anticlinal. *Spirifera arenosa*, *S. arrecta* and *Rensselœria avoides* occur in it. (Mr. Lewis Woolman in Proc. Ac. N. S. Phila., Aug. 3, 1886, page 296.) A similar show of Oriskany was reported as found subsequently on the other side of the Bald Eagle mountain in Clinton county

CHAPTER LXXXI.

No. VII, Oriskany fossils; Caudagalli grit fossils.

The formation is everywhere recognizable by the numerous unusually large shells crowded in eastern New York near the bottom. The most common and characteristic are *Spirifera arenosa* (old *Delthyris arenaria*); *Rensselæria ovoides* (old *Atrypa elongata*); *Orthis hipparionyx* (old *Hipparionyx proximus*) the same as Conrad's *Atrypa unguiformis*, resembling a colt's hoof.*

In the third volume of Prof. Hall's Palæontology of New York the reader will find descriptions and figures of the species of the following genera which occur (the genera) in the Oriskany formation and also in the formations underneath and above it: *Orthis*, *Strophodonta*, *Chonetes*, *Strophomena*, *Leptæna*, *Spirifera*, *Cyrtia*, *Rhynchonella*, and *Merista*; but the genera *Rensselæria*, *Eatonia* and *Leptocœlia* are more fully developed in the Oriskany than in the underlying formations (Hall's Pal. pp. 402). He gives also a few species of the lamellibranch genus *Avicula*, differing only in size from species of it found in underlying and overlying formations. The *Gasteropod* genus *Platystoma* furnishes its typical species both to No. VI and No. VII; and in some degree to No. VIII. *Strophostylus* is equally characteristic of No. VI and No. VII. Several species of *Platyceras* are quite abundant in No. VII; two or more species of it occurring both in VI and VII; and two spiny species of it in VII and in the overlying limestone of VIII.

In spite therefore of the general abrupt change from the

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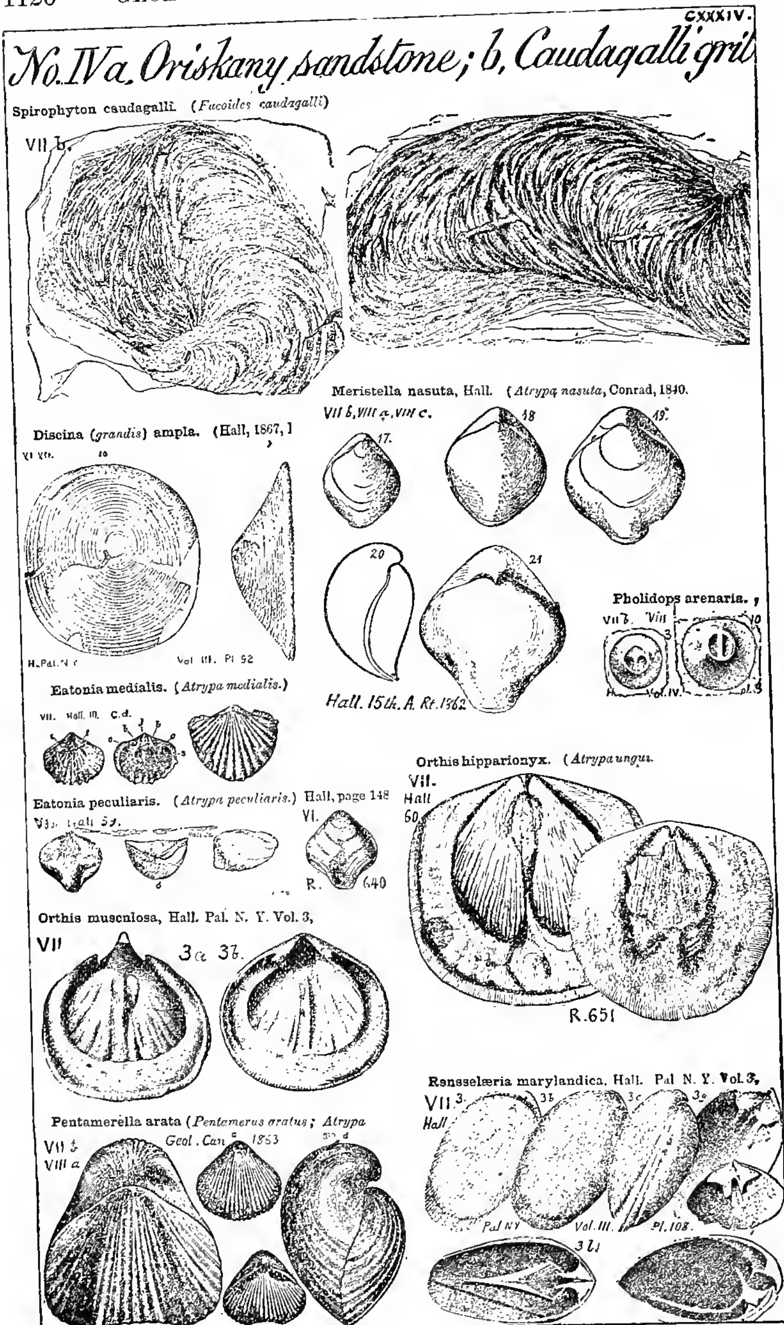
*Vanuxem's *Hipparionyx consimilis* is now known as *Atrypa reticularis*. These shells are 2″ or 2½″ in length and the last in breadth. Besides these a much smaller shell, *Eatonia peculiaris*, may be found in considerable numbers. *Spirifera arenosa* is a beautiful shell with a deep furrow and numerous flat ribs; but its cast occurs quite as frequently as the shell itself, is of a wholly different aspect, and has been called by farmers and quarry men by many fanciful names, chiefly that of *beeve's heart*.



CXXXIV.
No. IV a. Oriskany sandstone; b. Caudagalli grit
Spirophyton caudagalli. (Fucoides caudagalli)
VII b.
Meristella nasuta, Hall. (Atrypa nasuta, Conrad, 1840.
VII b, VIII a, VIII c.
17.
18
19.
20
21
Discina (grandis) ampla. (Hall, 1867,)
H. Pal. N. Y. Vol. III. Pl. 92
Hall. 15th. A. Rt. 1862
Pholidops arenaria.
Eatonia medialis. (Atrypa medialis.)
VII. Hall, III. C.d.
Orthis hipparionyx. (Atrypa ungui.
VII.
Hall
60
Eatonia peculiaris. (Atrypa peculiaris.) Hall, page 148
VI.
R. 640
Orthis musculosa, Hall. Pal. N. Y. Vol. 3,
VII
3a 3b.
R. 651
Rensselæria marylandica, Hall. Pal N. Y. Vol. 3,
VII 3. 3b 3c
Hall
Pal NY Vol. III. Pl. 108.
3 d
Pentamerella arata (Pentamerus aratus; Atrypa
VII b
VIII a
Geol. Can. 1863

limestone layers of VI to the nearly pure sandstone layers of VII (although in many localities the lower layers are more or less calcareous) Prof. Hall sees no marked break in the order of animal existence made by this remarkable deposit of sand. It was evidently an invasion of sand which for the moment, and only in certain areas or regions of the sea-bottom, suspended the life growth of the numerous shellfish which had been previously living and which undoubtedly continued to live elsewhere through the invasion; returning to their habitats on the return of the usual quiet calcareous deposit up to Marcellus times in which the great black mud sediments began to take the place of the limestone sediments.*

In New York state the Oriskany outcrop when followed westward seems to come to a feather edge at Cayuga lake

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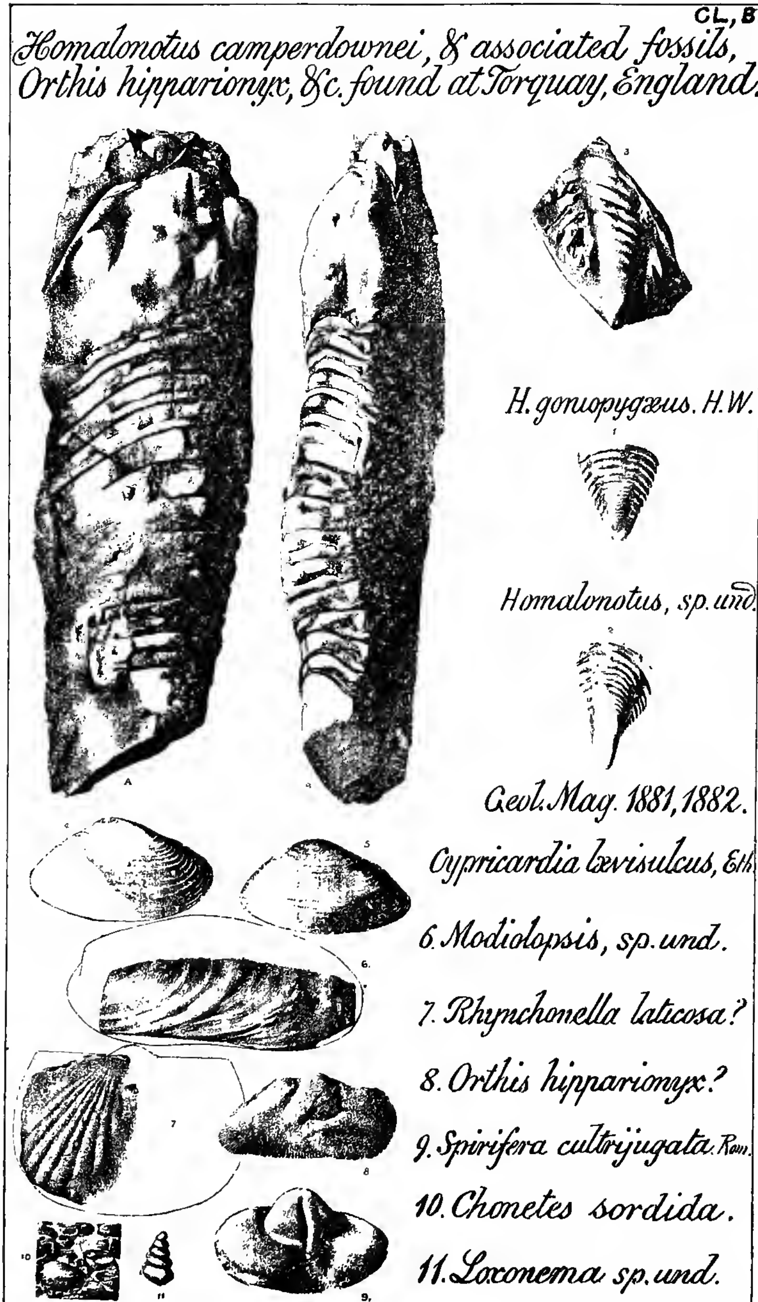
* He adduces the following instances of the continued life of certain genera of shells. The genus *Leptocœlia* gives one species to the Niagara (No. V), two to No. VI, two larger species to No. VII, and one or two more to the overlying formations. The genus *Eatonia* has four species in No. VI, and at least as many in No. VII, where they are more abundant, and one larger than the largest species of No. VI. The genus *Rensselæria* shows four species in No. VI, and then becomes exceedingly developed in No. VII, not so much in number of species as of individuals and their great size; but at least three species continued to live in No. VIII. Hall, Pal. 402. He concludes with these words "It is not possible therefore to point out any changes in the fauna of the [Oriskany] formation sufficient to indicate the commencement of a new system; and its relations with the formations below are as intimate as with those above; while in the northern and middle states the Oriskany sandstone bears in its fauna a closer relation to the lower than to the overlying formations. It is, moreover, in the State of New York, separated from the succeeding fossiliferous rocks of the Upper Helderberg group [No. VIII] by the non-fossiliferous or almost non-fossiliserous belt of the Caudagalli grit, which often attains a thickness of 100′ to 150′. It may be regarded that the physical conditions which inaugurated the Oriskany sandstone prevailed through the period of the Caudagalli grit, disappearing in the Schoharie grit and succeeding limestones." Then after speaking of the general similarity of strata upward to the Carboniferous, he goes on to say: "Therefore while in the central part of their extent we must regard the Oriskany sandstone as more close y allied in its fauna to the lower rocks, we find in other localities both in Pennsylvania and Canada, in the absence of the calcareous members of the higher groups a more intimate relation between the Oriskany sandstone and the succeeding sedimentary formations; making it in fact, under the circumstances, the base of a set of strata which culminated in a period favorable to the production of land plants, and which again in other parts, in the absence of calcareous beds, form an unbroken series up to the base of the coal measures."


CL, B.
Homalonotus camperdownei, & associated fossils,
Orthis hipparionyx, &c. found at Torquay, England.
H. goniopygæus. H.W.
Homalonotus, sp. und.
Geol. Mag. 1881, 1882.
Cypricardia lævisulcus, Eth.
6. Modiolopsis, sp. und.
7. Rhynchonella laticosa?
8. Orthis hipparionyx?
9. Spirifera cultrijugata. Rœm.
10. Chonetes sordida.
11. Loxonema sp. und.

where it is still fossiliferous; but in Ontario county, west of the lake, it locally re-appears again and again, several patches of the formation having been deposited west of its main body. Still farther west its place is marked at one point by some nodules of dark colored non-fossiliferous sandstone. It has, however, been detected by Murray in western Canada; and a considerable nnmber of Oriskany fossils were collected by Mr. Billings in Cayuga county of western Canada. In Illinois, Worthen has noticed both the sandstone and its characteristic fossils; and in Iowa a layer of coarse sand or gravel lies upon the water-worn upper beds of the Onandaga salt group, showing how far the sand invasion of No. VII extended westward. But Dana recognizes the formation over the northwestern states as a limestone mass.

On the Delaware the Oriskany shales hold *Spirifera arenosa* and *arrecta*, *Eatonia peculiaris*, *Meristella* ——?, *Rensselæria ovoides*, *discina jervensis*,* *Pterinea textilis var. arenaria*, *Platyceras gebhardi* and *ventricosum*, and *Tentaculites elongatus*.†

At Walpack Bend the Oriskany has a top conglomerate under which are sand shales holding *Spirifera macropleura* and other fossils of No. VI. These are White's Stormville shales, under which lies his Stormville conglomerate.

At Marshall's Falls collections were made from the Oriskany, and catalogued in O3, p. 208, where we find :—*Spirifera arenosa* and *arrecta*.

On Broadhead's creek were got: *S. arenosa*, *R. ovoides*, *O. hipparionyx*, *P. ventricosum*, and fragments.

The Bossardville quarries show no fossils whatever in VII.

On the Lehigh fossils of VII are very rare.

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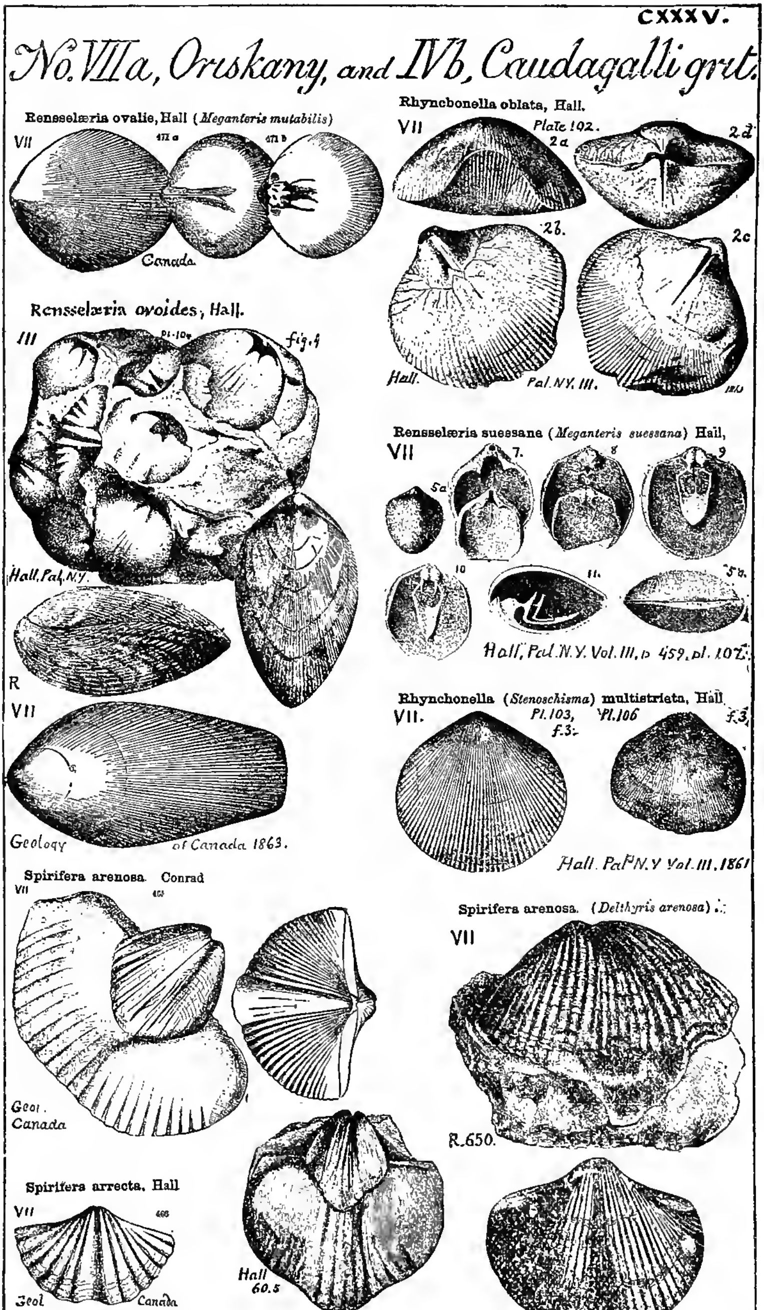
*So named by Dr. Barrett, but not figured, in Annals of N. Y. Acad. Sci. Vol. 1, No. 4.—White's Report G6, p. 123.

†See diagram section in Geol. New Jersey, 1868, in which Prof. Cook shows No. VII as a mass of shale, 120′ thick, lying upon 8′ of sand, or sandstone, over No. VI limestone. Some of the shales are calcareous, others gritty. Fossils are quite abundant, especially in the upper shale layers near the Caudagalli grit. A fine collecting ground is along Chamber's mill brook, N. W. of Isaac Bonsall's house. Some layers close under the Caudagalli grit are crowded with casts of *Spirifera*, *Platyceras*, etc.


CXXXV.
No. VIIa, Oriskany, and IVb, Caudagalli grit.
Rensselæria ovalis, Hall (Meganteris mutabilis)
VII
Canada
Rensselæria ovoides, Hall.
III
fig. 4
Hall. Pal. N.Y.
R
VII
Geology of Canada 1863.
Spirifera arenosa. Conrad
VII
Geol. Canada
Spirifera arrecta, Hall
VII
Geol Canada
Hall 60.5
Rhynchonella oblata, Hall.
VII
Plate 102.
2a
2d
2b.
2c
Hall.
Pal. N.Y. III.
Rensselæria suessana (Meganteris suessana) Hall,
VII
5a
7.
8
9
10
11.
5b.
Hall, Pal. N.Y. Vol. III, p 459, pl. 102.
Rhynchonella (Stenoschisma) multistriata, Hall.
VII.
Pl. 103, f. 3.
Pl. 106
f. 3.
Hall. Pal. N.Y. Vol. III, 1861
Spirifera arenosa. (Delthyris arenosa)
VII
R. 650.

Spirifer macropleura in New York has always been found beneath the Oriskany No. VII, never in it. *Spirifera arenosa* has always been accounted a characteristic form.* But in Montour county, Pennsylvania, while Prof. White finds the *macropleura* in the 100′ of Stormville shales beneath the coarse sandstone layers of No. VII, he finds a coarse Spirifer which he cannot distinguish from *arenosa* in the sand block layers (4′) under the shales and over the limestone of No. VI; only 56′ over the Stromatopora bed.† If now we take *S. arenosa* as proof of Oriskany age, the Sand block becomes the base of No. VII, and the Stormville shales should be called *Oriskany shales;* as was done by Dewees, Ashburner and Billin in their report on the Juniata valley district, where they found *S. arenosa* in them.‡ On the other hand if we take *S. macropleura* as proof of Lower Helderberg age, the Stormville shales are not part of No. VII, but belong to No. VI; and White took this view in Pike and Monroe counties, where he named the shales.§ The truth seems to be that the *macropleura* of the No. VI limestone reappeared in the limy shales; and that the

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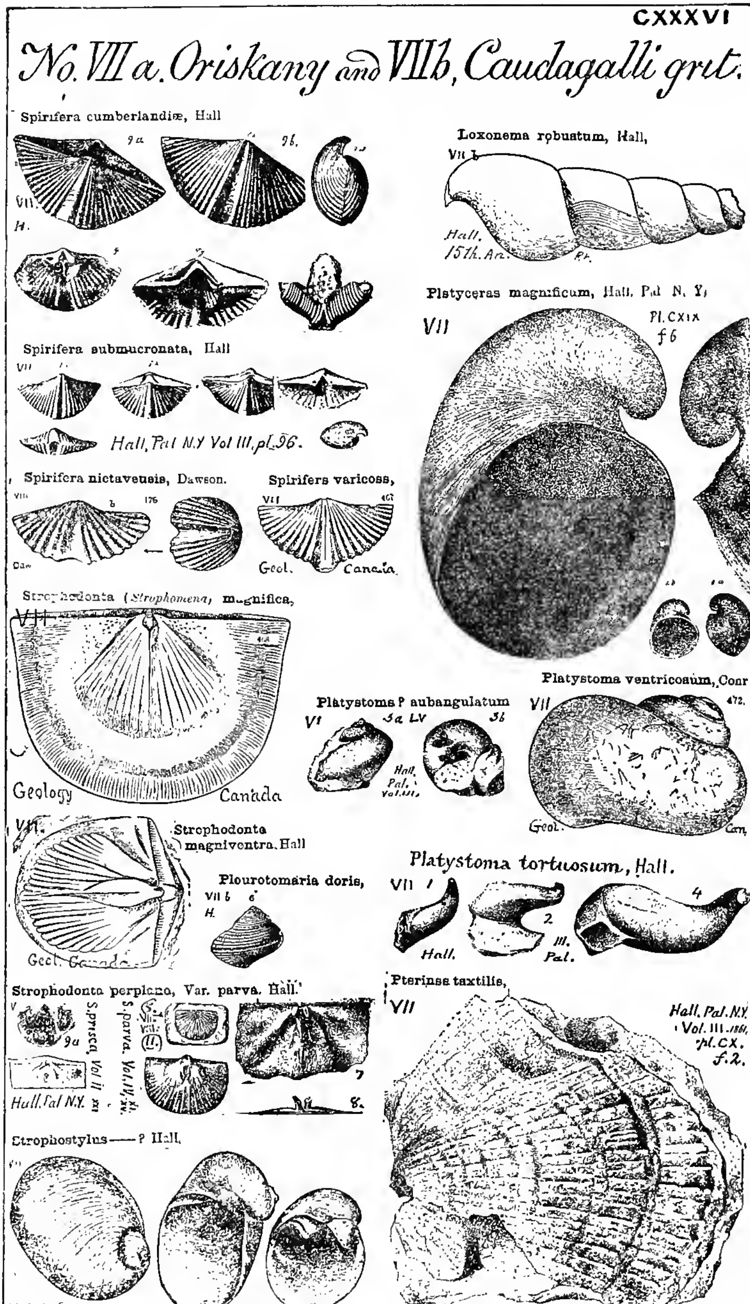
*Hall in preface to G7, p. xxiii, 1885.

†It is easy to satisfy the New York Palæontology by making the sand-block the base of No. VII; and in fact the Stormville shales are called *Oriskany shales* in Report F (1878, Dewces, Ashburner and Bittin) on the Jnniata district in central Pennsylvania, where they vary in thickness from 50′ to 200′, overlying the Lewistown (No. VI) shale and limestone mass of several hundred feet, and underlying the Oriskany sandstone (No. VII) mass varying from 25 to 160′ in thickness. In Huntingdon county these Oriskany shales 31′ thick hold *S. arenosa* and many other forms (see F, p. 239).

‡F, p. 239. The Oriskany sandstone from Lewistown to Orbisonia varies from 25′ to 160′; the Oriskany shales, from 50 to 200′. See in section in F, p. 239, at Three Springs, Huntingdon county, where No. VII sandstone is 104′ and shales 31, containing *S. arenosus* and many other forms. Prof. White found it in the upper part of the sandstone mass at Huntingdon (T3, p. 259).

§Report G6, 1882, p, 123. The Oriskany sandstone where it enters Pennsylvania from New York at the eastern corner of Pike, is merely a bed of *limy* cherty shales holding Oriskany fossils. These are called *Oriskany shales* and among their fossils is *S. arenosus.* The sandstone over them (and under the Caudagalli) comes in and thickens westward to 45′ at Stroudsburg, and 200′ at Lehigh. The underlying shales are 150′ in eastern Monroe, and hold *S. macropleura* and other L. Helderberg forms. Underneath these *Stormville shales* is a conglomerate (10′+) and then the No. VI limestones. On the Lehigh where the Oriskany sandstone is so thick, there are no shales under it, but it rests directly on the limestones.


CXXXVI
No. VII a. Oriskany and VIIb, Caudagalli grit.
Spirifera cumberlandiæ, Hall
Loxonema robustum, Hall,
Hall, 15th. An. Rt.
Platyceras magnificum, Hall. Pal N. Y.
Pl. CXIX f 6
Spirifera submucronata, Hall
Hall, Pal N.Y Vol III, pl. 96.
Spirifera nictavensis, Dawson.
Spirifera varicosa,
Geol. Canada
Strophodonta (Strophomena) magnifica,
Geology Canada
Platystoma ventricosum, Conr
Platystoma ? subangulatum
Hall, Pal. Vol. III
Geol. Can.
Strophodonta magniventra, Hall
Pleurotomaria doris,
Platystoma tortuosum, Hall.
Hall. Pal.
Geol. Canada
Strophodonta perplana, Var. parva. Hall.
S. prisca, Vol II
S. parva. Vol. IV.
Hall. Pal N.Y.
Pterinea textilis,
Hall. Pal. N.Y. Vol. III. 1861. pl. CX. f. 2.
Strophostylus —— ? Hall.
Hall. III. 5

arenosa of the Sand block reappeared in the No. VII sandstone above. In this way they became interlocked, each retaining its connection with its own favorite kind of deposit; and neither of them being characteristic of an unchanging horizon.

On the N. Br. Susquehanna Prof. White states (G7, p. 86) that he found no trace of an Oriskany outcrop on either side of the Montour anticlinal between Berwick and Bloomsburg; but on Little Fishing Creek at the Slate Quarry he found 4′ to 6′ of cherty beds full of the characteristic Oriskany shell *Spirifera arenosa* directly overlaid by the blue-black Marcellus shales. On the south outcrop west of Fishing Creek the Oriskany comes in and increases rapidly westward, furnishing *Spirifera arenosa, arrecta and submucronata; Orthis musculosa; Rensselæria ovalis and oblata; Discina ampla; Leptocœlia flabellites, Platyceras magnificum and tortuosum; Platystoma ventricosum.*—Down the river on the Selinsgrove arch No. VII, 57′ thick, is filled with its characteristic fossils.

In the Perry and Juniata county lists of Claypole's fossil collections (F2, preface, p. xiii) no mention is made of Oriskany species; and it is stated that no Corniferous forms were found in his district.*

At Orbisonia in Huntingdon county the coarse sandstone, 31′ thick, furnished specimens of the brachiopod shells *Eatonia peculiaris, Megambonia lamellosa, Orthis hipparionyx, Rensselæria marylandica, ovalis, ovoides, Spirifera arenosa, arrecta;* the lamellibranch shell *Pterinea textilis;* the gasteropod shells *Cyrtoceras expansum, Platyceras ventricosum;* and the trilobite *Dalmanites micrurus.*†

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*In the catalogue of Claypole's collections in O3, p. 130, is noted *Orthis hipparionyx* in various places in Perry county —See also p. 141.—Also p. 151, from Grove Bros. quarry near Bloomsburg, Columbia county. *S. arrecta; Pl. magnificum* and *ventricosum; Merista lata; Leptocoelia flabellites; R. ovalis.*—Also, Mapleton, Hunt Co. *R. ovoides: S. arrecta; Platystoma ventricosum; Megm. lamellata: Platyceras platystoma, conicum,* var. *inornatum, conicum* var. *inflectum, plicatum* var. *planum.*

†In C. E. Hall's special collection and catalogue (O3, p. 208) some of the above are represented by many specimens, one *R. ovoides* having a peculiar sculpture. The additional species from Orbisonia are *Atrypa reticularis*

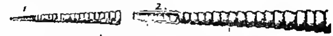
CXXXVII.

No. VII, Oriskany and Caudagalli (concluded)

Orthoceras baculum, Hall.

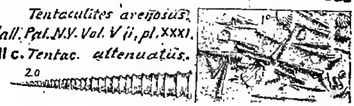
Tentaculites attenuatus, Hall.

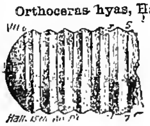
VII.



Tentaculites arenosus, Hall. Pal. N.Y. Vol. V (i), pl. XXXI.

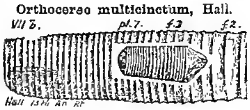
VIII c. Tentac. attenuatus.



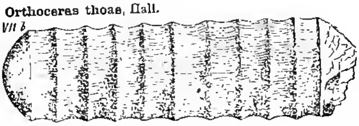


Orthoceras hyas, Hall.

Trochoceras clio, Hall.



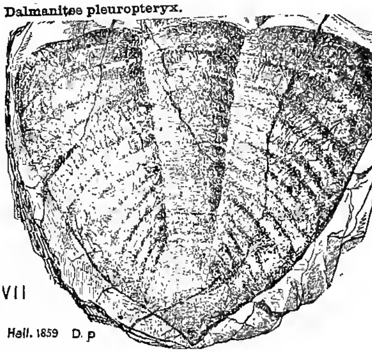
Orthoceras multicinctum, Hall.



Orthoceras thoas, Hall.

VII

Dalmanites pleuropteryx.



Hall. 1859 D. p

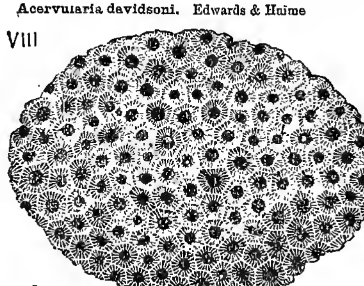
No. VIII a, Corniferous Limestone (Upper Helderberg).

Sphenophyllum vetustum, Newberry,

VIII a. Cornif. L.
Newberry.
Cin. S.N.H
Nov. 1889
p.55.

Acervularia davidsoni. Edwards & Haime

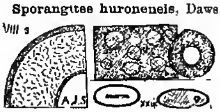
VIII



Ind. 1881

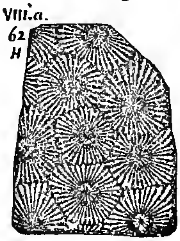
Sporangites (*Protosalvinia*) bilobata, Dawson.

Sporangites huronensis, Dawson



Acervularia rugosa

VIII. a.
62
H



Favosites alveolaris.

VIII. a.
61.
Hall.

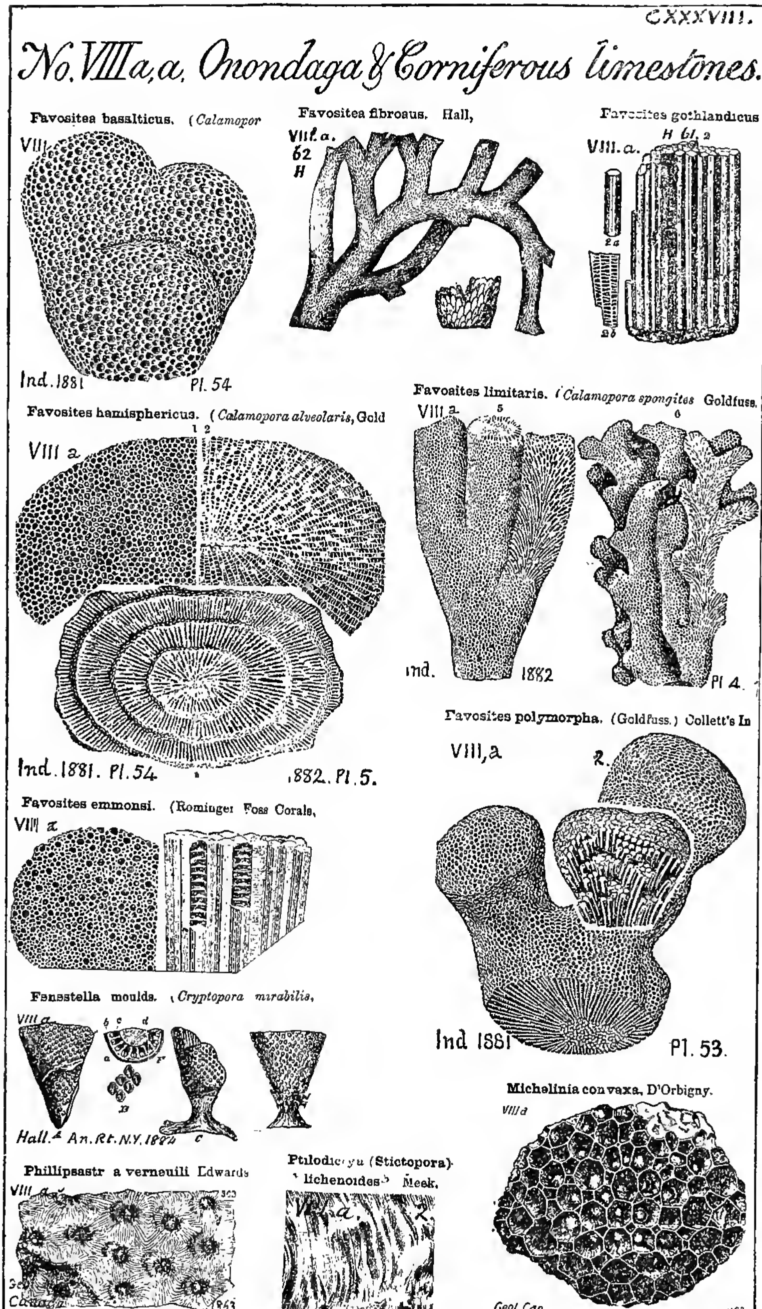
In Blair county the Oriskany is in places full of shells.

In Bedford county, Stevenson's Hindman section, on Will's creek (T2, p. 86 given also on page above) divides the 158′ into eight groups of beds, some of which are calcareous and rich in fossil shells; as for example the third and seventh from the top. He collected *Spirifera arenosa*, *arrecta*, and *cumberlandiæ*; *Merista lata*; *Rensselæria ovalis*, and *suessana*; *Eatonia singularis*; *Strophodonta magnifica*; *Streptorhynchus* (*Orthis*) *hipparionyx*; a *Megambonia*; a *Platyceras*; a *Platystoma*; and *a fucoid* in the seventh group. The eighth or bottom group (20′ thick) very cherty and persistent throughout the district, contains *Spirifera arenosa*, *Platyceras*, and abundance of *Favosites helderbergiæ*. It is a group of true passage beds from VI up into VII.

In Maryland James Hall collected from large pot holes in the Oriskany strata filled with soft reddish earth quantities of fossils as beautifully preserved as if they had been boxed up in cotton. Among them were exquisite stone-lily heads set with plated arms which rose from the sides of the calyx and curled over inward. No doubt such natural museums could be discovered in Bedford county.*

(1), *Avicula textilis* var. *arenaria* (2); *Bellerophon bilobatus; Cyrtolithes expansus* (3); *Orthoceras conscriptum; Platystoma subangulatum* (like Hall's fig. 3, pl. 55, Vol. 3); *Platystoma ventricosum; Pentamerus galeatus*, and another species; *Platyceras plicatum; Rhynchonella* (*Stenochisma*) *multistriata; Reptaria stolonifera* (encrusting Orthoceras conscriptum); and *Strophomena rugosa* (obscure).

* The Maryland outcrops run on through Virginia carrying the celebrated Low Moor deposits of Oriskany iron ore. S. A. Miller's summary of the characteristic fossils is as follows:—*Spirifera arenosa, arrecta, pyxidata; Rensselæria ovoides; Orthis proximus, musculosa; Strophodonta magniventra, magnifica; Cyrtina rostrata: Eatonia peculiaris; Leptocoelia flabellites; Platystoma ventricosum.* In some places in Virginia the shells are silicified and quite free from adhering matter, and the exterior markings and internal structure are well preserved; even the internal coils of brachiopods are beautifully represented. Near Cumberland, Md., a few elegant crinoids have been found, and one Cystidean, *Anomaloeystites disparilis*, which is the latest known representative of that order, except *Strobilocystites calvini.* The brachiopods are Devonian in their character rather than Silurian, and there is a graduation to the suceeding rocks through the Caudagalli grit, which bears few fossils. The nature of the deposit is not such as to preserve land plants; but they should have preserved fish teeth if any then existed; but no trace of such have been discovered. (N. Amer. Geol. and Pal. 1889, p. 58.)


CXXXVIII.
No. VIIIa,a. Onondaga & Corniferous limestones.
Favosites basalticus. (Calamopor
VIII
Ind. 1881 Pl. 54
Favosites fibrosus. Hall,
VIII a.
62
H
Favosites gothlandicus
H 61, 2
VIII. a.
2 a
2 b
Favosites hemisphericus. (Calamopora alveolaris, Gold
1 2
VIII a
Ind. 1881. Pl. 54
1882. Pl. 5.
Favosites limitaris. (Calamopora spongites Goldfuss.
VIII a
5
6
Ind. 1882
Pl 4.
Favosites polymorpha. (Goldfuss.) Collett's In
VIII, a
2.
Ind 1881
Pl. 53.
Favosites emmonsi. (Rominger Foss Corals,
VIII a
Fenestella moulds. (Cryptopora mirabilis,
VIII a
Hall. An. Rt. N.Y. 1884
Phillipsastr a verneuili Edwards
VIII a
Geol Canada
1863
Ptilodictya (Stictopora) lichenoides Meek.
VIII a.
2
Michelinia convaxa, D'Orbigny.
VIII a
Geol Can
1863

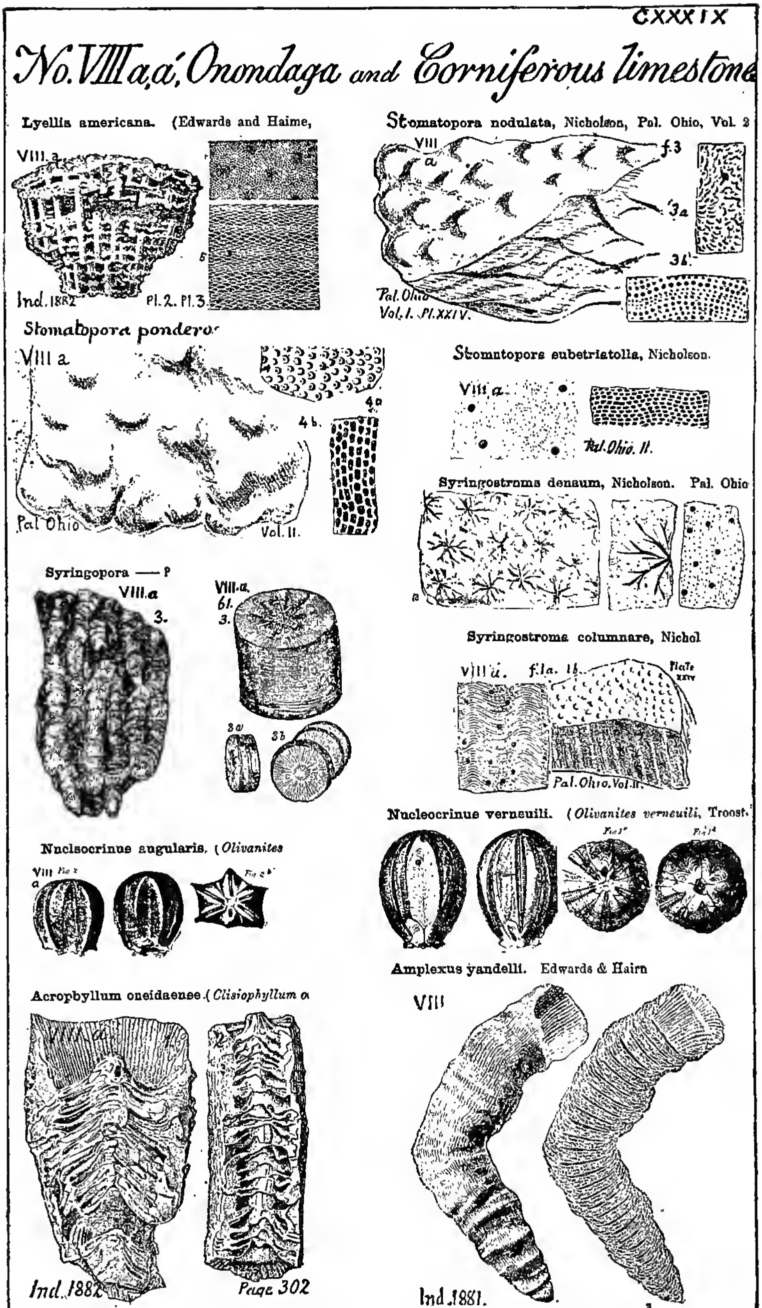
The great trilobites of Lower Silurian times had not all perished before this time, for a superb *Calymene-like* specimen was found some years ago in the upper shaly part of the sandstone near Kingston, N. Y. which when perfect must have measured about 15½ inches long and 5½ broad.* It received the name of *Homalonotus major* because the largest known species known until then was the English *Homalonotus rudis*, probably 12″ long, described by Salter. †.

Dana says of the Oriskany age that remains of seaweeds in it are not uncommon, but no land plants have been seen in it in the United States. But in New Brunswick, at Gaspé, on the shore of the Gulf of St. Lawrence, in limestone beds referable to the Oriskany age, Dawson found his *Psilophyton princeps*, a *Lycopodium* or Ground Pine, a plant without flowers, belonging to the Acrogens or highest division of the Cryptogams, growing to about the height of the common American species of the present day *Lycopodium dendroideum.* ‡

* See a fine life-size picture of the part preserved (5 of the 13 throat segments and the tail piece with its 8 center ribs, 6¾″ long) by R. P. Whitfield, in Bull. Mus. Nat. Hist. N. Y. Vol. 1. No. 6, 1885.

† Palæont. Soc. Vol. XVII, p. 109, as quoted by Whitfield. The distinction between the genera Calymene and Homalonotus is based upon the fact that the first has three strongly marked lobes, whereas the second has scarcely any side lobes, the great central lobe falling away on both sides to a flat margin. This genus began apparently with Simpson's *H. trentonensis* in the Trenton age (No. II *e*) and lived on long after the Oriskany age (No. VII); for the large *Homalonotus* of Torquay in the south of England, described by A. Champerdown and H. Woodward in the London Geol. Mag. for Nov. 1881, was found in beds referable to either the top of the Lower or the bottom of the Middle Devonian of Europe. Additional figures of this *H. camperdownii* were published with an additional note by H. Woodward in G. M. April, 1882, accompanying notes of some fossils from the Red Beds of the Lower Devonian, Torquay, by R. Etheridge. Among these are specimens of *Orthis hipparionyx*, which in America is regarded as a peculiarly characteristic fossil of the Oriskany. The trilobite and the brachiopod shell may have lived together in American earlier than they lived together in European waters.

‡ The Gaspé rocks assigned to this age are wonderfully fertile in fossils. *R. ovoides*, *S. arenosus*, *Taonurus caudagalli*, and three species of *Chonetes* occur in the upper 500′ of the Gaspé limestones, mixed with *Favosites gothlandicus, basalticus, cervicornis ; Zaphrentis ; St. rhomboidalis, beckii,* and *perplana ; Lepto. concava* and *flabellites ; Eat. peculiaris ; Atry. reticularis ; Meristella lævis ; Modiolopsis ; Avicula ; Murchisonia ; Loxon-*


CXXXIX
No. VIII a, a'. Onondaga and Corniferous limestone
Lyellia americana. (Edwards and Haime,
VIII. a
Ind. 1882
Pl. 2. Pl. 3.
Stomatopora nodulata, Nicholson, Pal. Ohio, Vol. 2
VIII a
f. 3
3a
3b
Pal. Ohio Vol. I. Pl. XXIV.
Stomatopora pondero
VIII a
4a
4b.
Pal. Ohio
Vol. II.
Stomatopora subetriatolla, Nicholson.
VIII a.
Pal. Ohio. II.
Syringostroma densum, Nicholson. Pal. Ohio
Syringopora —— ?
VIII. a
3.
VIII. a.
61.
3.
3a
3b
Syringostroma columnare, Nichol
VIII a.
f. 1a. 1b.
Pal. Ohio. Vol. II.
Nucleocrinus verneuili. (Olivanites verneuili, Troost.
Nucleocrinus angularis. (Olivanites
VIII a
Amplexus yandelli. Edwards & Haim
VIII
Acrophyllum oneidaense (Clisiophyllum o
Ind. 1882
Page 302
Ind. 1881.

As for shellfish they lived in such multitudes that masses of rock are made up of the stony casts of *S. arenosa* and *R. ovoides*. Among the gasteropods *Platyceras* were most numerous, their floating marine shells (related to the modern *Janthina*) drifted together in heaps. Crinoids, so rare in New York, are abundant in Maryland. *Mariacrinus*, *Edriocrinus*, etc. and three species of Cystids, one *Anamolocystes* resembles the *A. cornutus*, figured in Dana's Manual on page 238.

Fossils of the Caudagalli Grit.

This formation is placed by Dana and others in the Upper Helderberg group because its dark gritty slates (confined to eastern New York, where its maximum thickness on the Mohawk hills is 60′), contrasting with the light-colored massive Oriskany sandstone beds underneath them are covered with the impressions of the cock-tail seaweed *Taonurus caudagalli*. It graduates upward into another local formation, the *Schoharie Grit*, above which come in the great coral reef limestone beds of the *Corniferous formation*, a modified re-production of the Lower Helderberg limestone deposits of No. VI, which spreads throughout the United States and Canada Were it not for their fossils

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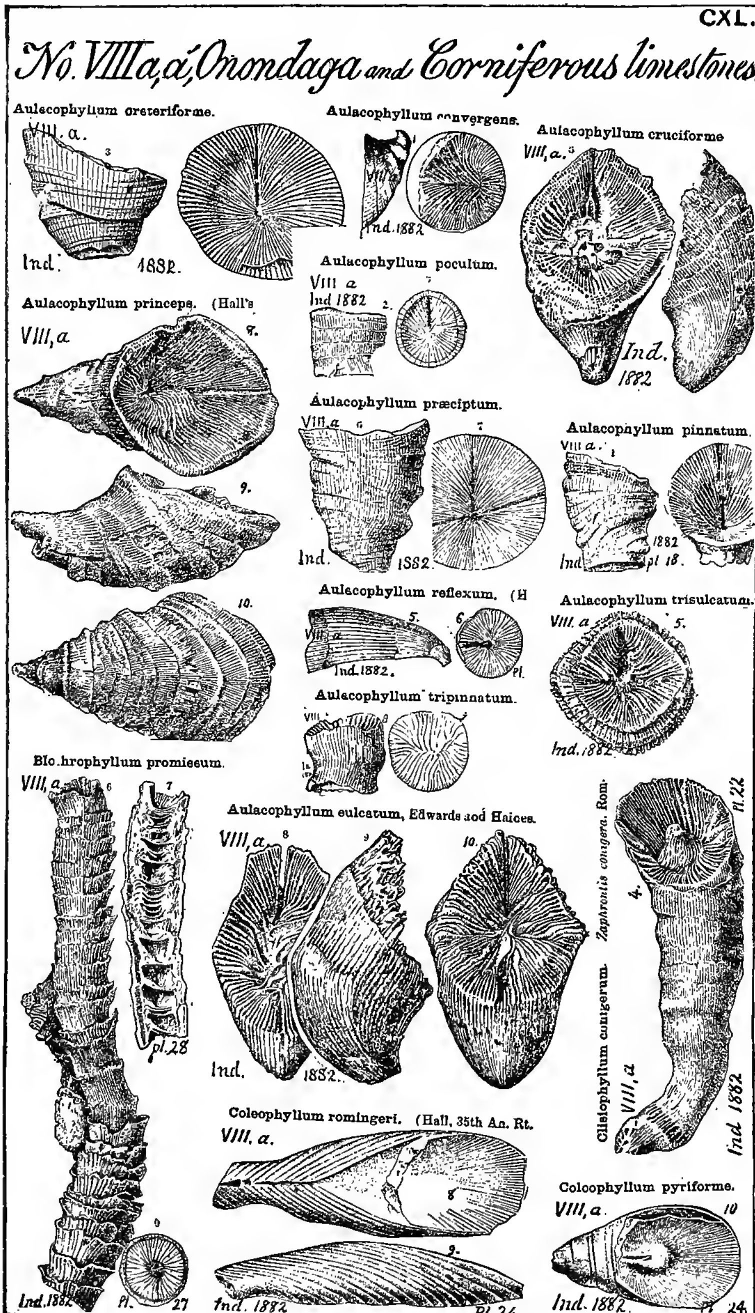
ema; Orthoceras; Phacops; Prœtus; Dalm. pleuroptyx; etc. The *Taonurus* extends down abundantly for 800′. Surely nothing could be more effective for impairing the credit of characteristic time species. (Dana's Manual.)

He adds that some Oriskany *Spirifers* have a peculiarity observed in America in only one Silurian (Niagara) species, that of split or forked ribs; a peculiarity which, in Europe, does not appear until Devonian times.

The extension of the Oriskany sandstone with its characteristic fossils to Europe is one of the most striking facts. At the Congress in 1879 the lamented Hébert opened drawer after drawer in his cabinet in the Sorbonne to show to James Hall and myself groups of specimens from outcrops in the northwest of France which had we seen them in America we should have recognized as collections from the outcrops of New York and Pennsylvania, both the lithology and the palæontology being familiar. It is needless to say that this is a proof of the possibility of characteristic lithological and palæontological horizons fairly offsetting the Gaspé limestone disclaimer. Nature cares no more for the embarasments of geologists than Providence does for the woes of individual men. Yet the orderly conduct of the Demiurge is as confidently to be trusted in the gross as is the wisdom and goodness of the Heavenly Father.


CXL.
No. VIII a, a', Onondaga and Corniferous limestones.
Aulacophyllum crateriforme.
Aulacophyllum convergens.
Aulacophyllum cruciforme
Aulacophyllum poculum.
Aulacophyllum princeps. (Hall's
Aulacophyllum præciptum.
Aulacophyllum pinnatum.
Aulacophyllum reflexum. (H
Aulacophyllum trisulcatum.
Aulacophyllum tripinnatum.
Blothrophyllum promissum.
Aulacophyllum sulcatum, Edwards and Haimes.
Zaphrentis congera. Rom.
Cistiophyllum conigerum.
Coleophyllum romingeri. (Hall, 35th An. Rt.
Coleophyllum pyriforme.
VIII, a
Ind. 1882

the Oriskany, Caudagalli and Schoharie would have been included in one variable sand formation between two great limestone formations, the Upper and Lower Helderberg.

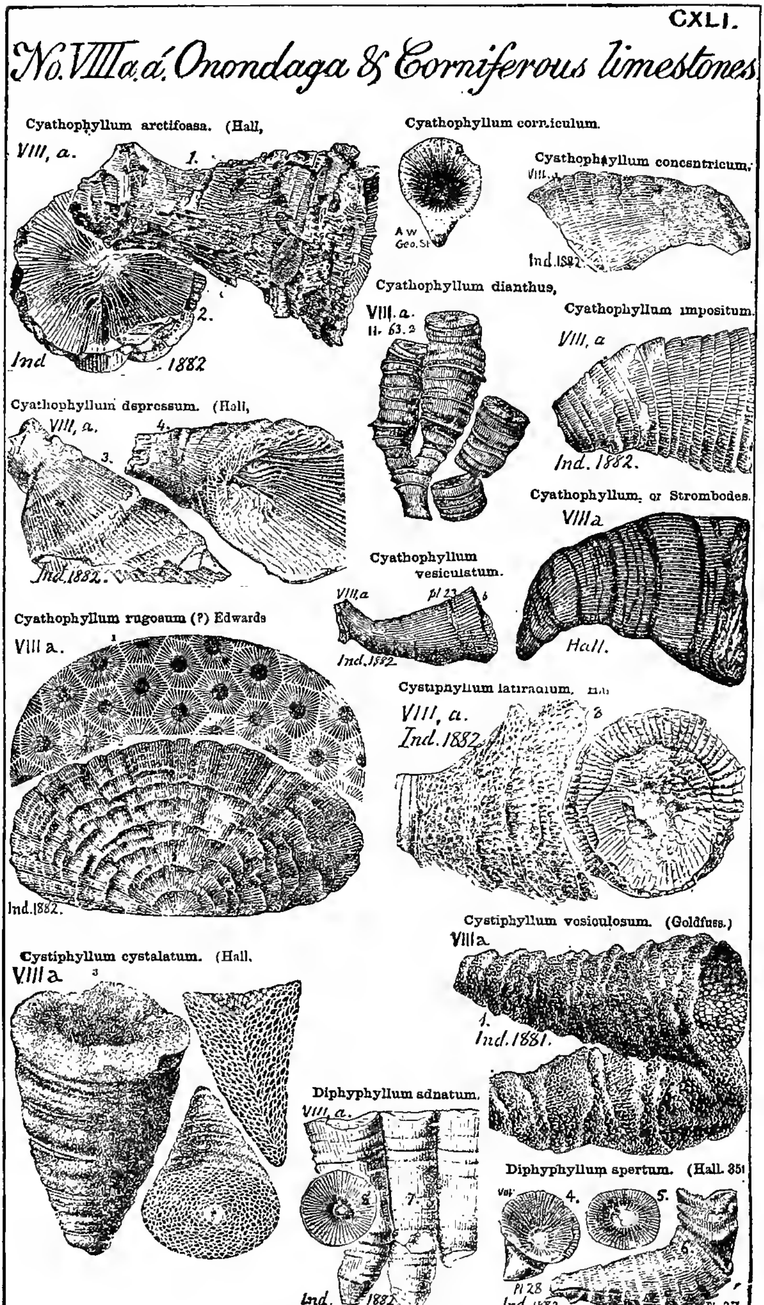
Fossils of the Schoharie Grit.

In this continuation upward of the Caudagalli grit the sandy slates begin to receive a charge of carbonate of lime, prophesying the coming of the coral age; or rather, as it is confined to eastern New York, like the Caudagalli grit, we see in it the deposits of the eastern shallow waters of the Appalachian sea.

The first scales and plates of fishes found in New York were found in the Scoharie grit. In Pennsylvania they are found in much earlier deposits, as described under No. V.

The Schoharie grit, placed by James Hall, not in the Oriskany but in the Upper Helderberg, holds the following lamellibranch shells: *Mytilarca* (*Pythomytilis*) *arenacea*, Hall; *Conocardium cuneus*, Conrad; and its variety, *attenuatum*, Conrad; and *Cypricardinia planulata*, Conrad.*

*MSS. list, 1886, of types in the State Museum at Albany, and figured in Pal. N. Y. Vol. V, part 1.—*Mytilarca oviformis* is a Hamilton species; *M. chemungensis*, *carinata*, *simplex*, *lata*, are all Chemung species. *Conocardium trigonale* is assigned by Hall to the Corniferous formation. *Cypricardinia planulata*, Con. is a Hamilton species.


CXLI.
No. VIIIa.a'. Onondaga & Corniferous limestones
Cyathophyllum arctifossa. (Hall,
VIII, a.
1.
2.
Ind 1882
Cyathophyllum corniculum.
A W Geo. St
Cysthophyllum concentricum.
Ind. 1882
Cyathophyllum dianthus,
VIII. a.
H. 63. 2
Cyathophyllum impositum.
VIII, a
Ind. 1882.
Cyathophyllum depressum. (Hall,
VIII, a.
3.
4.
Ind. 1882.
Cyathophyllum, or Strombodes.
VIIIa
Hall.
Cyathophyllum vesiculatum.
VIII, a
pl 23
Ind. 1882
Cyathophyllum rugosum (?) Edwards
VIII a.
Ind. 1882.
Cystiphyllum latiradium.
VIII, a.
Ind. 1882
Cystiphyllum vesiculosum. (Goldfuss.)
VIIIa
Ind. 1881.
Cystiphyllum cystalatum. (Hall,
VIIIa
Diphyphyllum adnatum.
VIII, a.
7.
Ind. 1882
Diphyphyllum apertum. (Hall. 351
4.
5.
Pl 28
Ind 1882
Pl. 27

CHAPTER LXXXII.

No. VIIIa, Upper Helderberg—Onondaga and Corniferous limestones.

The Caudagalli and Schoharie grits have been described under the head of Oriskany No. VII, although they are usually classed as the first and second subdivisions of the Upper Helderberg group, and the Onondaga and Corniferous limestones as the third and fourth subdivisions, for reasons given in the preceding chapters.

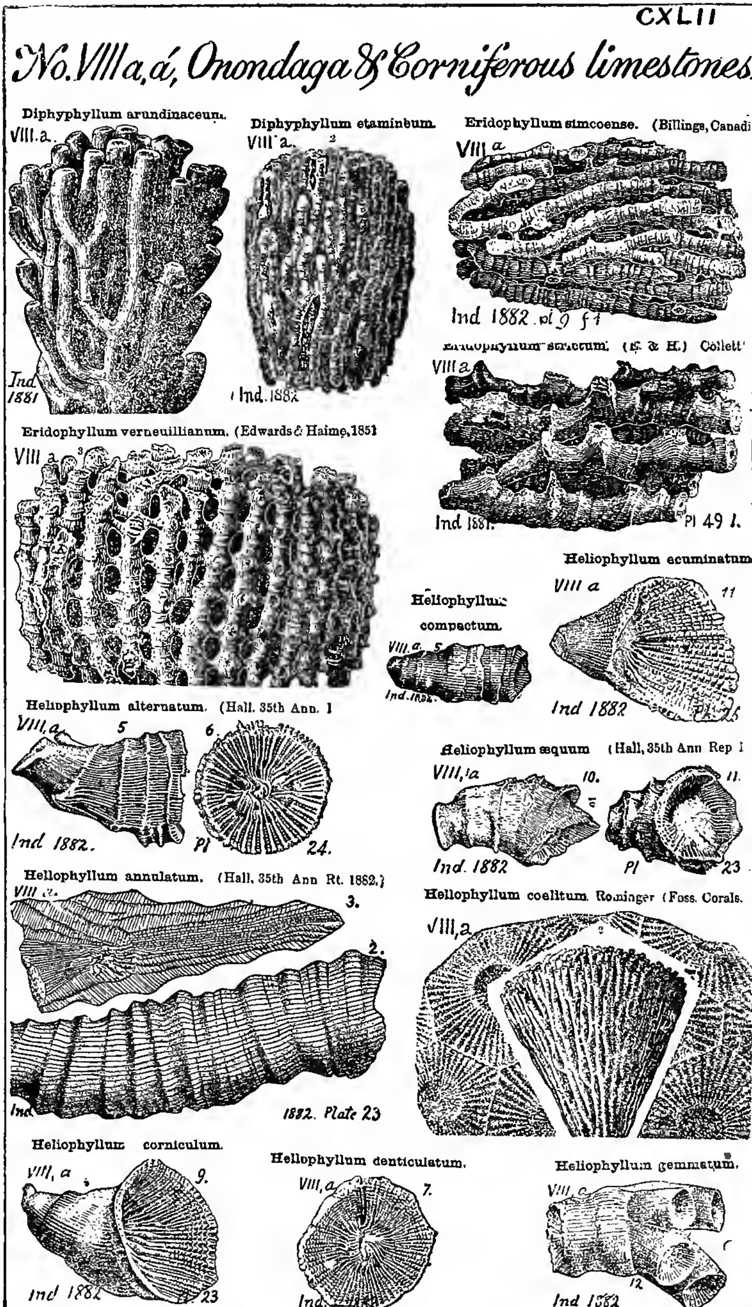
The Onondaga limestone.

This can be distinctly recognized in some parts of Pennsylvania, but its outcrop in New York has been so well described by Emmons, Conrad, Vanuxem, Hall and Mather, that a short summary of it will help field work in our State where its separation from the Corniferous has been ignored, and the name Corniferous has been used for all strata lying between the Oriskany and the Marcellus.

The *Onondaga limestone* (*Grey sparry limestone*) was made by Eaton the lower division of the *Corniferous.*

It extends its outcrop without interruption from the Hudson to the Niagara and far into Canada; therefore we have a right to suppose that its deposits underlie all southern New York and perhaps all northern Pennsylvania, although they are not recognizable where the *Oriskany* and *Caudagalli* (on which they lie) come up to the surface at the Bald Eagle mountain, in the Williamsport-Lock Haven valley. They may at any time be struck by some adventurous deep well borer in our northern tier of counties, and their character in New York should therefore be described.

The *Onondaga limestone* then is a set of light grey whitish semi-crystalline limestones, very fossiliferous, and sometimes almost a deposit of very finely ground-up corals and crinoids—in fact a coral shore-sand; in which however


CXLII
No. VIII a, á, Onondaga & Corniferous limestones.
Diphyphyllum arundinaceum.
VIII. a.
Ind 1881
Diphyphyllum etaminbum.
VIII a.
Ind. 1882
Eridophyllum simcoense. (Billings, Canadi
VIII a
Ind 1882. pl 9 f 1
VIII a
Ind 1881.
Pl 49 1.
Eridophyllum verneuillianum. (Edwards & Haime, 1851
VIII a.
Heliophyllum ecuminatum
VIII a
11
Ind 1882
Heliophyllum compactum.
VIII. a. 5
Heliophyllum alternatum. (Hall. 35th Ann. 1
VIII, a. 5
6.
Ind 1882.
Pl
24.
Heliophyllum æquum (Hall, 35th Ann Rep 1
VIII, a
10.
11.
Ind. 1882
Pl
23
Heliophyllum annulatum. (Hall. 35th Ann Rt. 1882.)
3.
2.
Ind
1882. Plate 23
Heliophyllum coelitum. Rominger (Foss. Corals.
VIII, a
Heliophyllum corniculum.
VIII, a
9.
Ind 1882
23
Heliophyllum denticulatum.
VIII, a
7.
Ind.
Heliophyllum gemmatum.
VIII, a
12
Ind 1882

are here and there preserved large fragments, especially of the stems of the stone lily; most of them of a pink color; with some shells; making a beautiful stone when polished; and a good building stone.* Sometimes the beds are fine grained, compact, darker, with fewer fossils; separated by green shale partings which often divide up the blocks into wedge shaped and irregular laminæ, and even when scarcely visible make it split under the hammer, injuring its building value.†

The *Onondaga hornstone*, *chert*, or *flint* is sometimes in interrupted thin layers; elsewhere in ranges of balls. But the dissolved silica was precipitated in various other ways in connection with the abundant coralline life of that age. For, sometimes the *favosites* are partially dissolved, and the cavities thus left are lined with silica in the form of chert (*chalcedony*), or of quartz crystals. The alimentary canal of the stone lily stems (*crinoids*) and the chambers of the straight horn (*Orthoceras*) cephalopods and of other shells are lined with rock crystals.

The Onondaga subdivision of the Corniferous formation is extremely variable in thickness along its New York outcrop.‡ Doubtless a similar variability characterized its

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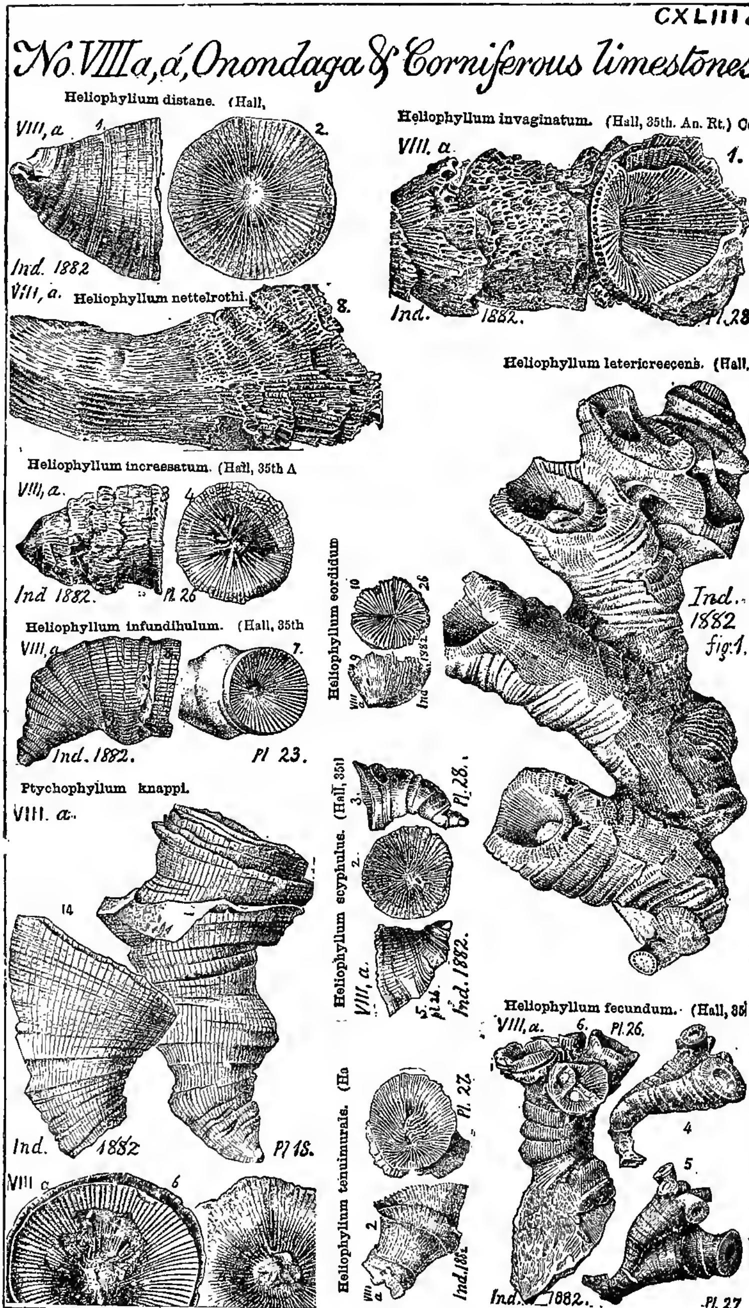
* The coral sand contains some dark earthy matter, bringing out in agreeable contrast the large whitish *favosites*, *cyathophylla*, etc. This may be seen in the LeRoy quarries from which the court house at Batavia was built. (Hall, 152.)

† When thus seamed and charged with encrinal stems and plates it strikingly resembles the Wenlock or Dudley stone of England. The Wenlock is supposed to be our Niagara. Therefore all the intervening formations, Oriskany included, seem to be American deposits absent in England; although the Oriskany is found in France.

‡ Its thickness in Seneca county is almost nothing; in Ontario county only 2 feet, resting directly on *Oriskany;* near Vienna it is in several layers; west of the Genesee river it is much thicker, compact and very full of fossils; at Le Roy it is a grey blue limestone without fossils, overlaid by 20′ of thin irregular layers of chert full of the usual *Onandaga* fossils, covered by limestones holding *Corniferous* fossils; only two miles from this the chert mass is thin, and the underlying limestones are in several thick regular layers, white with the abundance of broken crinoids and corals; further west the whole formation is in one bed less than 2′ thick: in Newstead, Erie, it is a one foot layer of nothing but the fossils, with a few lime laminæ and shale which weathers down so as to show coral masses in a ferruginous mud; west of Clarence Hollow it is a thick coarse-grained rock crumbling


CXLIII.
No. VIII a, á, Onondaga & Corniferous limestones
Heliophylium distane. (Hall,
VIII, a
Ind. 1882
VIII, a. Heliophyllum nettelrothi.
Heliophyllum invaginatum. (Hall, 35th. An. Rt.) Co
VIII. a
Ind. 1882.
Pl. 28
Heliophyllum latericrescens. (Hall,
Ind. 1882 fig: 1.
Heliophyllum incrassatum. (Hall, 35th A
VIII, a.
Ind 1882.
Pl. 26
Heliophyllum infundihulum. (Hall, 35th
VIII, a
Ind. 1882.
Pl 23.
Heliophyllum sordidum
Ptychophyllum knappi.
VIII. a.
Ind. 1882
Pl 18.
VIII a
Heliophyllum scyphulus. (Hall, 35t
Pl. 28.
VIII, a.
Ind. 1882.
Heliophyllum tenuimurale. (Ha
Pl. 27
Ind. 1882
Heliophyllum fecundum. (Hall, 35
VIII, a.
Pl. 26.
Ind. 1882.
Pl. 27.

northward extension over what is now the Lake Ontario region from which it has been removed ; and still exists in the region to the south into Pennsylvania, where it now lies at depths of several thousand feet. We must imagine the palæozoic sea dotted with coral banks ; * more or less separated ; small and scattered towards the west ; increasing in size and number and proximity to each other eastward ; for the outcrop is at its maximum on the Mohawk and Hudson rivers. †

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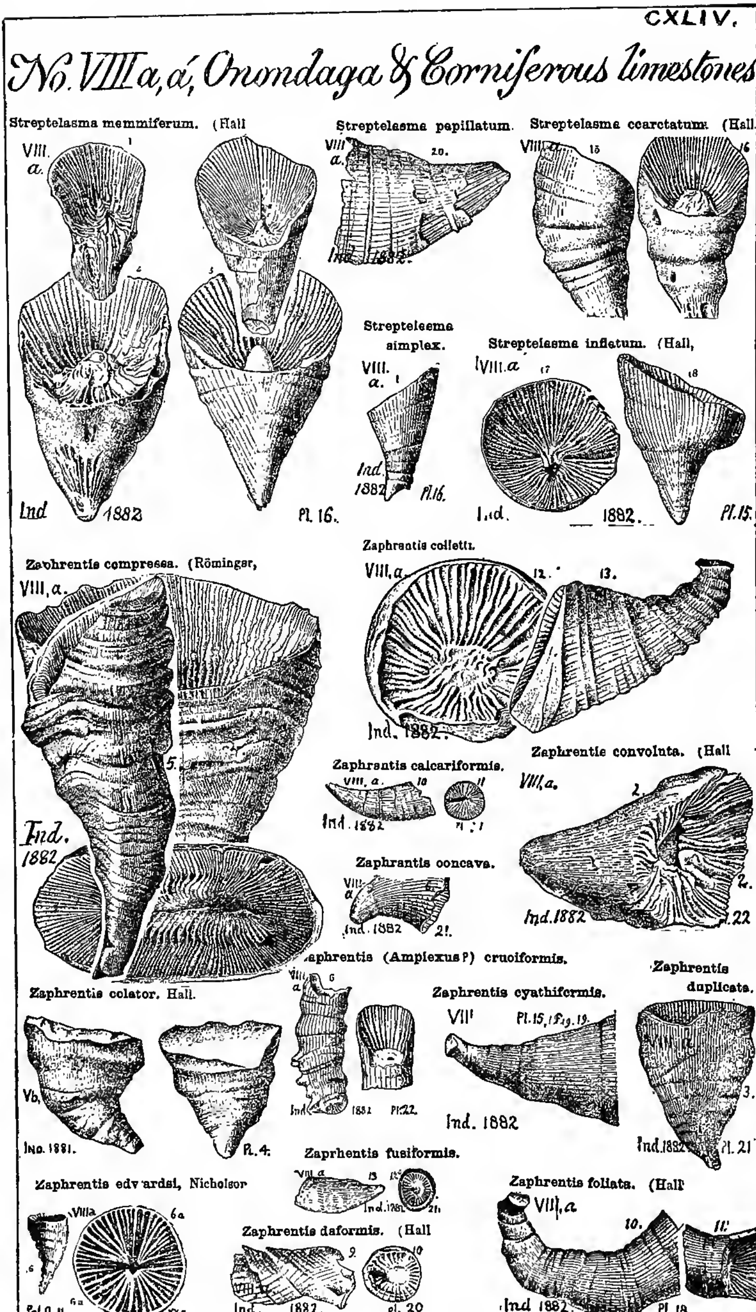
under the hammer, full of fossils, and sometimes wholly composed of *crinoids* and *cyathophylla* (cup corals) ; at Williamsville it is 20′ thick, with chert balls and its corals often silicified, the best exposure being at Youngs a mile west of the village ; thence it thins to Black Rock on Niagara river, where it is in one layer only 24 inches thick, while the chert mass over it becomes thick and contains some of its fossils. (Condensed from Hall, 154.)

* This is evident from the fact that many of the corals retain the position in which they grew ; some of the *favosites* are several feet in size ; from one mass several carloads were hauled away ; such could not have been transported far, if moved at all ; the smaller are broken up, some are turned over or reversed by the waves ; the banks of stone lilies were mowed down and their discs scattered, but columns a foot or more in length occur ; the *cyathophylla* are generally thrown down, but unbroken. The areas between the coral banks received the finer fragments and muds from a distance. Many delicate and fragile species of corals grew with the large and sturdy species, and we only find them in small pieces. The growth of coral is slow ; the size of some of these indicates a long lapse of time ; some of the crinoidal stems are more than half an inch thick. One reef was destroyed and covered over, and a new reef is seen to have grown up over it, and been in its turn destroyed in place. (Hall, 156.)

† Through Middle New York, although so persistent, the *Onandago limestone* rarely exceeds 10 to 15 feet. It is readily recognized by its light color, crystalline structure, toughness, and abundance of fossils. Generally nearly pure its beds ,in some places hold layers of flint balls. Its vertical jointing is very regular, in two systems nearly at right angles. At Split rock, southwest of Syracuse, the surface of the limestone is uncovered for more than a mile, where the canal contractors obtained their blocks.

Here the *lower layers* frequently contain *black pebbles* whose *water worn* character admits of no doubt ; showing when broken their identity with *Sandstone balls in the Oriskany quarry rock* south of Paris hill. These black rolled stones occur also in the *bottom layer* of the Onondaga limestone at the extensive quarries at the State Prison north of Auburn (Vanuxem 1842.) Nothing of this sort appears in Pennsylvania.—In New York, quarries of Onondaga stone are numerous and large. The beds furnish most valuable building stone ; beautiful as a marble, and so durable that it makes the rock channel of abandoned water courses and the ledges of picturesque cascades ; for example of the Canaseraga falls at Perryville, 120′, and Chittenango falls at Cazenovia. This makes the 12′ ledge on the Wederburg mountain top at the road from Fort Plain to Cherry Valley, and the floor of


CXLIV.
No. VIII a, a', Onondaga & Corniferous limestones
Streptelasma memmiferum. (Hall
VIII. a.
Ind 1882
Pl. 16.
Streptelasma papillatum.
VIII a.
Ind. 1882.
Streptelasma ccarctatum. (Hall
VIII a.
Streptelasma simplex.
VIII. a.
Ind. 1882
Pl. 16.
Streptelasma inflatum. (Hall,
VIII. a
Ind. 1882.
Pl. 15.
Zaphrentis collettı.
VIII, a.
Ind. 1882.
Zaphrentis compressa. (Römingar,
VIII, a.
Ind. 1882
Zaphrentis calcariformis.
VIII, a.
Ind. 1882
Zaphrentis convoluta. (Hall
VIII, a.
Ind. 1882
Zaphrentis concava.
VIII a
Ind. 1882
Zaphrentis (Amplexus?) cruciformis.
VIII a
Ind 1881
Pl. 22.
Zaphrentis colator. Hall.
Vb.
Ind. 1881.
Pl. 4.
Zaphrentis cyathiformis.
VIII
Pl. 15, Fig. 19.
Ind. 1882
Zaphrentis duplicata.
Ind. 1882
Pl. 21
Zaphrentis fusiformis.
VIII a
Ind. 1881
Zaphrentis edwardsi, Nicholson
VIII a
Pal. O. II.
Zaphrentis deformis. (Hall
Ind. 1882.
pl. 20
Zaphrentis foliata. (Hall
VIII, a
Ind 1882.
Pl 18.

It was a sea favorable for corals, but unfavorable for shell fish. A few univalves have been found; and more rarely some species of *Atrypa* and *Spirifera* (*Delthyris*) (Hall, 157).—The most common coralline forms are *Favosites alveolaris*, *Favosites gothlandicus*, *Favosites fibrosus*; *Astrea rugosa*, (159); *Cyathophyllum dianthus*; *Syringoporæ*; and Stone lilies (*Encrinites*,) (Hall's figures, 1843, pp. 157, 158, 160). *

Cyathophylla (*cup-leaf* corals) are abundant in the New York Onondaga, standing out in relief from the weathered surfaces of the rocks, usually in groups, bunches, and masses, turned to flint (silicified). Hall gives two in his report of 1843; the first one (perhaps a *Strombodes*) one of the common and abundant forms; in company with *C.* (now *Campophyllum*) *fluxuosum*; and with *C. ceratites*.†

Cherry Valley. Here the marks remain of the Delaware river floods when they used to pour northward, over the mountain top, into the Mohawk Valley, 1200′ below, before the uptilt of Canada and New York since the Lake Ontario terrace age.

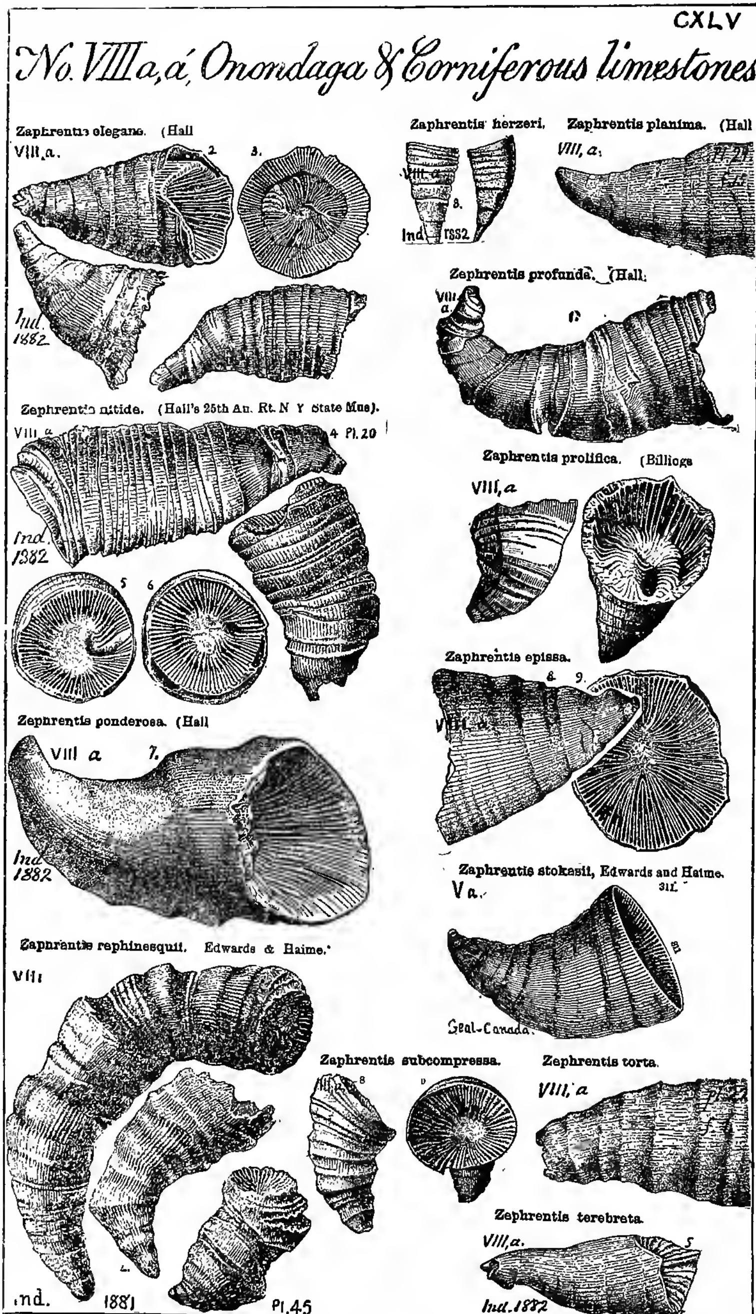
* *Favositis alveolaris* (De Blainville, 1834, Hall, 1843, "full of cells") is so called because honey-combed with cells; the transverse partitions (Septa) not continuous, but interrupted, each subdivision of each rod growth having its own set of chambers or stories from base to summit. The larger rods or columns show pores along the angles or edges, where the faces meet.

Favosites gothlandica (or *Oothlandicus*, Lamarck 1816) is exceedingly abundant in the Onondaga limestone in New York; but, so far from being peculiar to this age, it makes its appearance in the Niagara limestone of No. V; and continued to flourish through Clinton, Helderberg and Hamilton times. Some specimens show a single and a double row of pores on the same column. Some have their tubes filled with calcite; others are honeycombed with open cells.

Favosites fibrosa (*calamopora fibrosa*, Goldfuss, *Monticulipora fibrosa*, Goldfuss) is abundant in many places on the surfaces of the strata (Hall's Report 1843, p. 159). The figure natural size shows its manner of branching; the smaller figure of a portion magnified shows its structure, but not the transverse lamellæ.

Astræa rugosa (*acervularia rugosa;* perhaps *Cyathophyllum rugosum*), exhibits a pavement of stars set together like a mosaic and stopping each others growth at about three-fourths of an inch diameter. Each star of 36 rays has a small star of 18 rays in center, raised. The rays are all wrinkled lengthwise, giving the whole surface its peculiar roughness. The rays of one star pass into the adjoining stars, by bending more or less abruptly.

† *Cyathophyllum dianthus*, (Goldfuss; Love's goblet), usually appears in large bunches; the figure is of a small piece of a bunch.—*Campophyllum torquium* of Owen (*Cyathophyllum giganteum*; *gigas*, Randall and Shumard, Kentucky Devonian, 1847) occurs only in the Onondaga limestone, in Middle New York (Vanux. p. 133.) He says there are four other species.


CXLV
No. VIII a, a', Onondaga & Corniferous limestones
Zaphrentis elegans. (Hall
VIII, a.
2
3.
Ind.
1882
Zaphrentis herzeri.
VIII, a
8.
Ind. 1882
Zaphrentis planima. (Hall
VIII, a.
Pl. 21
Zephrentis profunda. (Hall.
VIII
a.
Zephrentis nitida. (Hall's 25th An. Rt. N. Y. State Mus).
VIII, a
4 Pl. 20
Ind.
1882
5
6
Zaphrentis prolifica. (Billings
VIII, a
Zaphrentis epissa.
8. 9.
VIII, a
Zephrentis ponderosa. (Hall
VIII a
7.
Ind.
1882
Zaphrentis stokesii, Edwards and Haime.
V a.
311
Geol.-Canada.
Zaphrentis rephinesquii. Edwards & Haime.
VIII
Ind.
1881
Pl. 45
Zaphrentis subcompressa.
8
Zephrentis torta.
VIII, a
Zephrentis terebrata.
VIII, a.
5
Ind. 1882

Syringopora (several species one of which Hall figures on page 160) is another kind of coral which often appears in western New York projecting from the weathered rock surfaces in high relief; or, otherwise, the ends only appear, broken off and showing their structure in the most perfect manner (Hall 160).

The huge *smooth stone lily*, *Encrinites lævis*, grew in vast abundance; the largest species in New York geology with stems an inch in diameter sometimes, and usually more than half an inch; extremely thin plates or discs; nearly always converted into lamellar calcite; some pink, some milk white, contrasting prettily with the green shale partings. Stems a foot long and more have been found. Sometimes larger and smaller plates alternate. Hall figures three plates that have slipped past each other. He shows their crenulated edges. *

The shell *Amphigenia* (*Pentamerus*) *elongata* is only found in the Onondaga, and in middle New York is generally diffused throughout it, the largest measuring 5 inches long by 2½ inches thick from shell to shell. † *Spirifera* (*Delthyris*) *undulata* differs from *S. macropleura* in that its ribs are not so round, and show lines of growth.—*Atrypa reticularis* (*Hipparionyx consimilis*) has turned up in several places in middle New York and Pennsylvania. Other shells, thought to be characteristic of the Onondaga by Conrad before 1840, appear in Vanuxem's and Mather's reports, and have been renamed and figured by Hall. ‡

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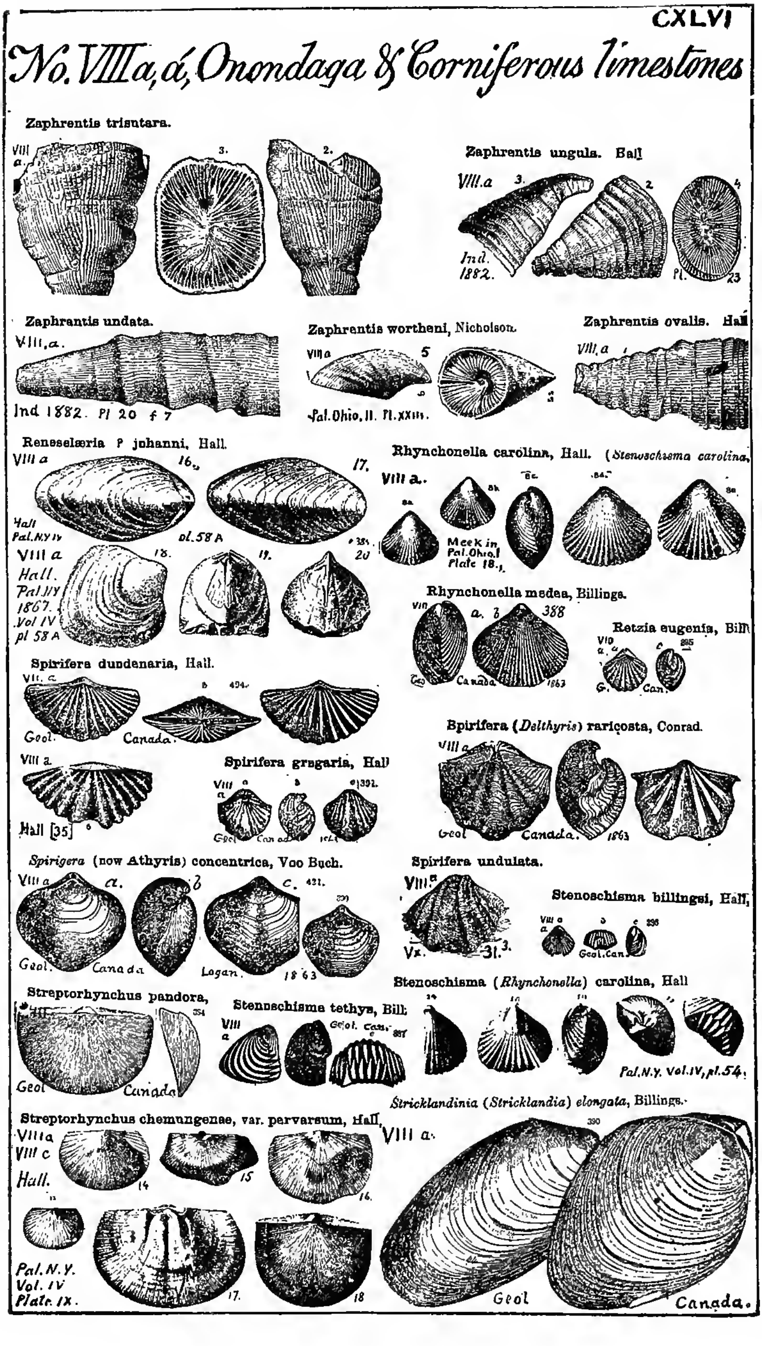
* *Corniferous* forms, silicified, in drift bowlders, at Ann Arbor, were found by Dr. Röminger, State Geologist of Michigan. Among them was a *new* Bryozoan *Patellipora stellata* (Fig. 10), in the lower left hand corner of Plate 1. Proc. Acad. Nat. Sci., Phila., Pa., 1887, Vol II.

† Prof. Hall says (p. 160) that he only found this shell at Vienna in Western New York, and that the other two, which Vanuxem considered characteristic of the formation in the eastern half of its New York outcrop, do not characterize the western half (1843, p. 160).

‡ The shells of Conrad's original list are now known as *Spirifera raricosta*, *Strophomena gibbosa*, *Strophodonta perplana*, *Meristella nasuta* and *unisulcata*, *Leptocœlia acutiplicata*, *Aviculopecten pectiniformis*, *Cypricardites inflatus*, *Bellerophon curvilineatus*, *Pleurotomaria poulsoni* *Platyceras unisulcatum*, *Dalmanites aspectans*. Vanuxum speaks of three species of *Platyceras* and three of *Platystoma*. He also figures a fishbone or spine.


CXLVI
No. VIII a, á, Onondaga & Corniferous limestones
Zaphrentis trisutara.
Zaphrentis ungula. Hall
Ind. 1882.
Zaphrentis undata.
Ind 1882. Pl 20 f 7
Zaphrentis wortheni, Nicholson.
Pal. Ohio, II. Pl. XXIII.
Zaphrentis ovalis. Hall
Renesselæria ? johanni, Hall.
Hall Pal. N.Y. IV pl. 58 A
Hall. Pal. N.Y. 1867. Vol IV pl 58 A
Rhynchonella carolina, Hall. (Stenoschisma carolina,
Meek in Pal. Ohio. I Plate 18.
Rhynchonella medea, Billings.
Geol Canada 1863
Retzia eugenia, Bill.
Spirifera duodenaria, Hall.
Geol. Canada.
Hall [35]
Spirifera gregaria, Hall
Spirifera (Delthyris) raricosta, Conrad.
Geol Canada. 1863
Spirigera (now Athyris) concentrica, Von Buch.
Geol. Canada. Logan. 1863
Spirifera undulata.
Stenoschisma billingsi, Hall,
Geol. Can.
Stenoschisma (Rhynchonella) carolina, Hall
Pal. N.Y. Vol. IV, pl. 54.
Streptorhynchus pandora,
Geol Canada
Stenoschisma tethys, Bill.
Geol. Can.
Stricklandinia (Stricklandia) elongata, Billings.
Geol Canada.
Streptorhynchus chemungense, var. perversum, Hall,
Hall.
Pal. N.Y. Vol. IV Plate IX.

The Corniferous Limestone Proper.

The New York outcrop is as regular in respect of the beds and of the fossils they contain* as that of its lower subdivision (Onondaga) is irregular. Its uppermost layers were called *Seneca limestone*, because holding in special abundance the shell *Strophomena rhomboidalis* (*linearis.*) †

Its outcrop extends from Schoharie westward along the Mohawk and the little lakes into Upper Canada; and from Kingston southwestward along the Delaware river valley into Pennsylvania. If a straight line be drawn from the outlet of Lake Erie to the Delaware water gap, a distance of 250 miles, passing through Buffalo, Hornellsville, Towanda, Pittston and Stroudsburg, we have a right to say that all the counties of New York and Pennsylvania northeast of that line are underlaid (at various depths) by a continuous sheet of *Corniferous limestone* beds, rising and falling over underground anticlinals and synclinals; no where appearing at the surface, or even approaching it closely; but sinking into the anthracite basin at Pittston, 10,000′ feet beneath it.

Southwest of this line it must undergo a marked change of character; for it is quite a different looking formation; where it comes to the surface at Berwick (25 miles S. W. of Pittston) at Muncy (80 miles S. W. of Towanda); and along its numerous continuous outcrops in the Juniata region. How this change proceeds in the underground of northern Pennsylvania can only be inferred from what is

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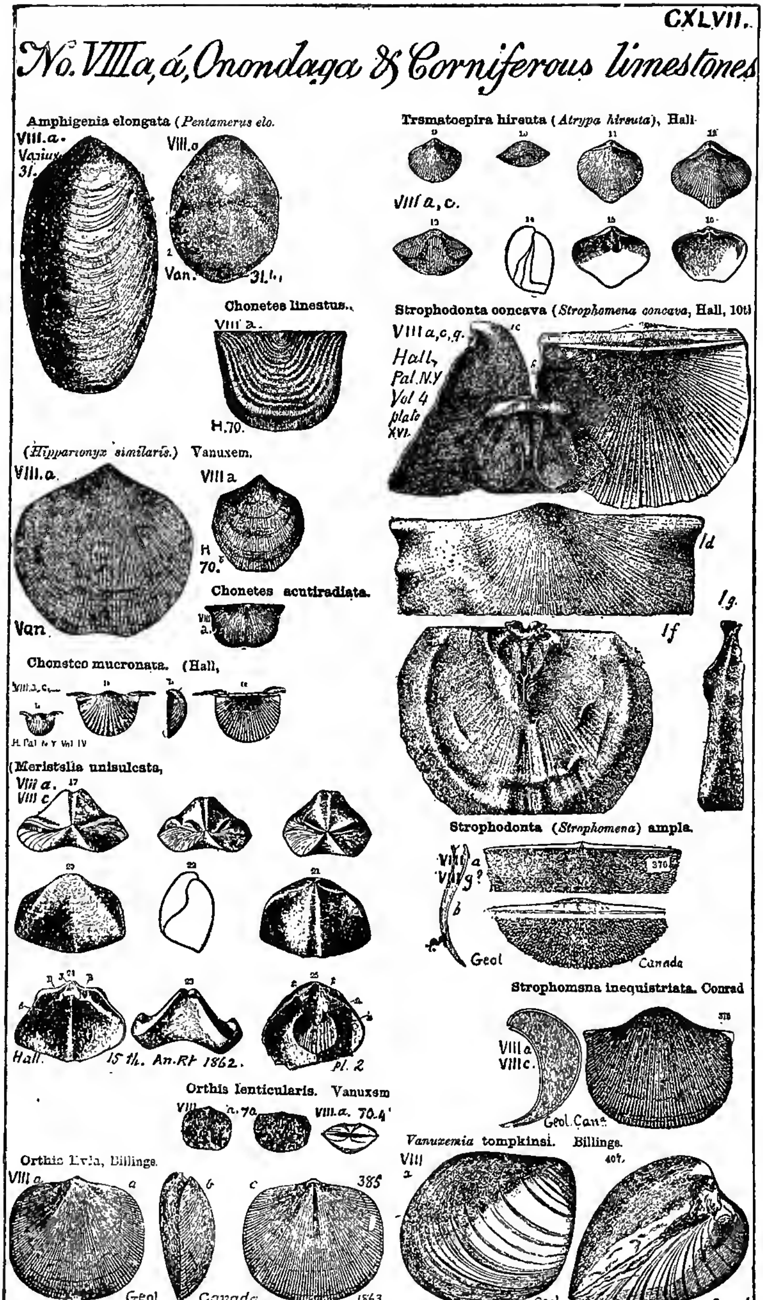
*The following *characteristic lamellibranch shells* are assigned to the *Corniferous* formation in Prof. Hall's MS. list (1886) of types in the State Museum at Albany, and figured in Pal. N. Y., Vol. V., part 1, viz: *Aviculopecten cleon*, Hall; *Conocardium cuneus, var. trigonale*, Hall; *Paracyclas elliptica*, Hall.

† Eaton's name, *Corniferous limestone*, might have been given to all the limestones of New York from the Niagara upwards, for they all contain flint; and the *Corniferous limestone* varies greatly in different localities as to the presence or absence and quantity of its flints. It seldom yields a pure lime; it is impure as a whole, and especially its lower layers. Those which contain flints are usually very compact; rarely any layer shows a crystalline grain; most of them are mixed with shale and even in excess. The formation is darker in middle than in eastern New York.


CXLVII.
No. VIIIa, á, Onondaga & Corniferous limestones
Amphigenia elongata (Pentamerus elo.
Trematospira hirsuta (Atrypa hirsuta), Hall.
VIII a, c.
Chonetes lineatus.
H.70.
Strophodonta concava (Strophomena concava, Hall, 10t)
VIII a, c, g.
Hall, Pal. N.Y. Vol 4 plate XVI.
(Hipparionyx similaris.) Vanuxem.
VIII. a.
VIII a
Van.
Chonetes acutiradiata.
Chonetes mucronata. (Hall,
H. Pal. N. Y. Vol IV
(Meristella unisulcata,
VIII a.
VIII c
Strophodonta (Strophomena) ampla.
Geol Canada
Strophomena inequistriata. Conrad
VIII a
VIII c.
Hall. 15 th. An. Rt 1862. pl. 2
Orthis lenticularis. Vanuxem
Vanuxemia tompkinsi. Billings.
Orthis Livia, Billings.
Geol Canada 1863

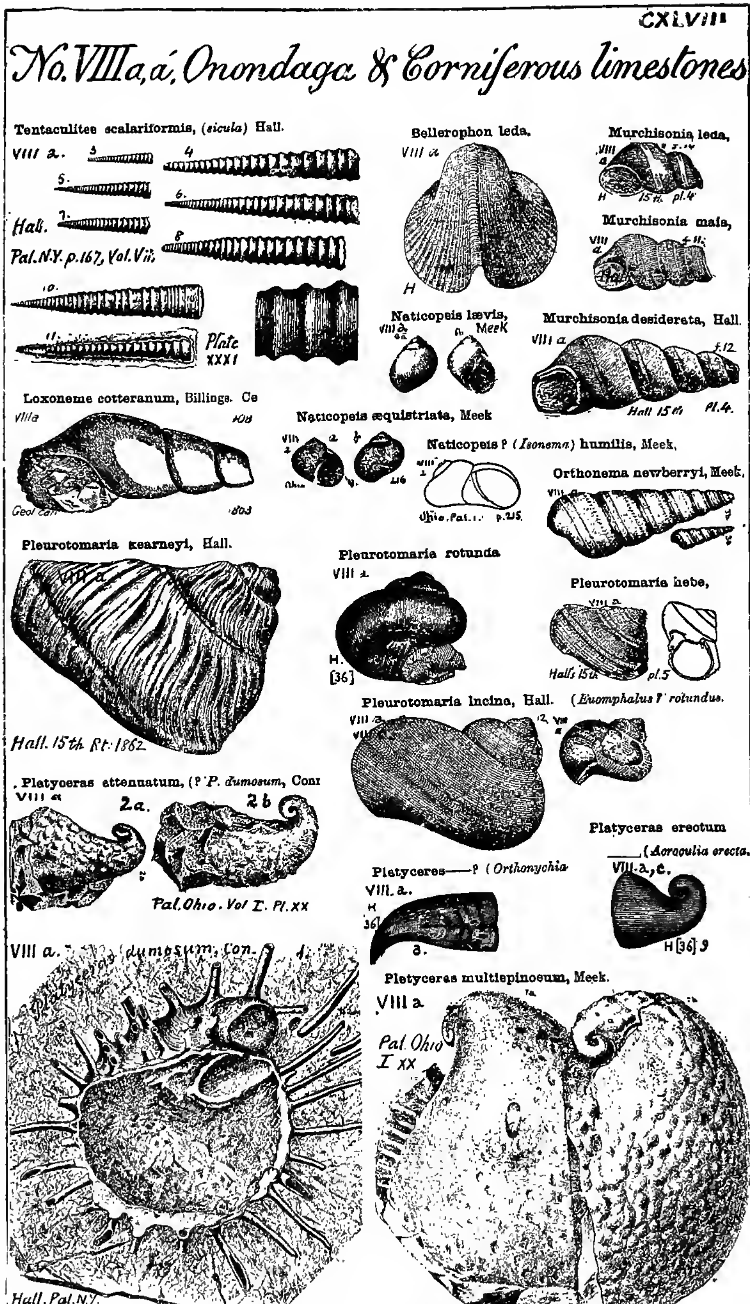
seen of it at its Delaware river outcrop, a few miles southwest of Stroudsburg (to be described in the following pages), where the change is so sudden and complete as almost to amount to an extinction of the formation and the substitution of another in its place. All that we can say is that if wells were bored to a sufficient depth in our northern tier of counties, they would probably strike the formation more with its New York aspect east of the Williamsport and Elmira railroad; and more with its Pennsylvania aspect west of that road.

But this change of aspect does not affect the integrity of the formation; nor is there any call for a change of name. To infer that the New York *Corniferous limestone* extends southward and westward to some regular or irregular geographical line; there ceases to exist; and is replaced by another limestone spreading southwestward,—an inference based solely on the comparative plenty or poverty of flints, fossils, and black mud,—is illogical; because, what makes an essentially limestone formation is its limestone; not the admixture of black mud and silica; nor the species of animals which lived at the time. A limestone formation deposited in a certain age over the entire sea bottom must be impressed with different features in different parts of the sea, and sustain different kinds and quantities of living creatures. The fact that it is on the whole a great *formation of limestone* is the fact that gives it its unity and individuality.

This is especially true of the *Corniferous formation*, which represents the end of the great Upper Silurian age of limestone deposits (in spite of the intervention of the Oriskany); and the beginning of the great Devonian age of mud and sand deposits, which lasted uninterruptedly (in New York and Pennsylvania) far into the age of coal.*

We have seen that during the *Lower Helderberg* (*Lewistown*, *Bossardville*, *Stormville*) age the sea bottom became covered with hundreds of feet of limestone mud, pure in

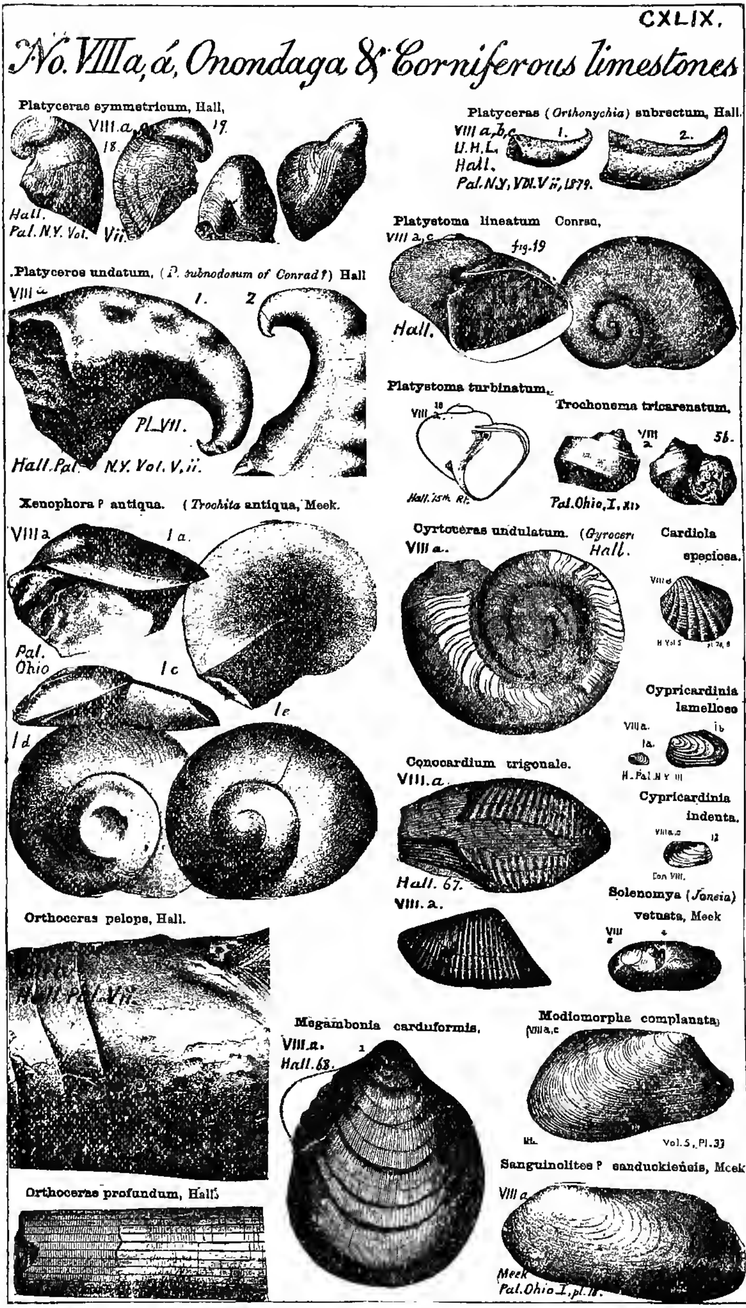
*The long subsequent appearances of thin *Tully limestone* and *Mauch Chunk limestone* are of slight account in this discussion.


CXLVIII
No. VIII a, a', Onondaga & Corniferous limestones
Tentaculites scalariformis, (sicula) Hall.
VIII a.
Hall.
Pal. N.Y. p. 167, Vol. VII.
Plate XXXI
Bellerophon leda.
VIII a
H
Murchisonia leda,
Murchisonia maia,
Naticopsis lævis, Meek
Murchisonia desiderata, Hall.
VIII a
Hall 15th pl. 4.
Loxonema cotteranum, Billings.
VIIIa
Naticopsis æquistriata, Meek
Naticopsis ? (Isonema) humilis, Meek,
Orthonema newberryi, Meek,
Pleurotomaria kearneyi, Hall.
Pleurotomaria rotunda
VIII a.
H.
[36]
Pleurotomaria hebe,
Hall's 15th pl. 5
Pleurotomaria lucina, Hall. (Euomphalus ? rotundus.
Hall. 15th Rt. 1862
Platyceras attenuatum, (? P. dumosum, Con
2a.
2b
Pal. Ohio. Vol I. Pl. XX
Platyceras erectum
(Acroculia erecta.
VIII. a, c.
H [36]
Platyceras ——? (Orthonychia
VIII. a.
H
36
VIII a. (dumosum, Con.
Platyceras multispinosum, Meek.
VIII a
Pal. Ohio
I XX
Hall. Pal. N.Y.

some places, clayey in others, but nowhere essentially sandy. We have also seen that the *Middle Helderberg* (*Oriskany*, *Caudagalli*) age, there was a wide spread but not universal invasion of quantities of glass sand, pure in some places, mixed with ferruginous and limy mud in others. We have now to see that in the *Upper Helderberg* (*Onondaga*, *Corniferous*) age, the sand invasion come to an end and the preceding state of things restored,—a quiet sea, in which deposits of lime mud recommenced but with a modification of color ; a disposition to *black lime* mud. In some places we see *black clay muds* alternating with tolerably pure *blue lime muds ;* in other places black clay mud, heavily charged with iron, and almost no lime mud ; here an abundance of animal life, coral reefs, crinoid groves; there a desolated sea bottom covering itself with coral sand, and silt from distant continental rivers. In the more western regions, to which the sand invasion had not reached, these *Upper Helderberg lime deposits* were a direct continuation of the *Lower Helderberg lime deposits ;* but with peculiar new developments of animal species ; and under the influence of a generally changed condition of things around the sea coasts (wherever they were), and in the ocean currents which distributed the different shells over different regions of sea bottom.

We shall see in the next chapter this Helderberg age not ending but merging into the Devonian (Marcellus, Hamilton, Tully, Genesee) age,—as one century of human history slides insensibly into the next,—with no abrupt change of events ; without a cataclysm ; retaining on its own bosom its own characteristic facts, like fossils in a rock formation, by which it prepares and assists the next century to manufacture characteristic analogous facts, to be fossilized in it as time proceeds.

The *Corniferous formation* acquired its *New York aspect* from great quantities of gelatinous or fluid silica, set free in that age in the northern and eastern regions from some unknown source by some unknown process and deposited, locally here and there in solid plates alternating with contemporary sheets of lime mud, which afterwards became


CXLIX.
No. VIIIa, á, Onondaga & Corniferous limestones
Platyceras symmetricum, Hall,
VIII.a.
18.
19.
Hall.
Pal. N.Y. Vol. Vii.
Platyceras (Orthonychia) subrectum, Hall.
VIII a, b, c.
U.H.L.
Hall.
Pal. N.Y. VII. V ii, 1879.
1.
2.
Platystoma lineatum Conrad,
VIII a, c
fig. 19
Hall.
.Platyceros undatum, (P. subnodosum of Conrad?) Hall
1.
2
Pl. VII.
Hall. Pal. N.Y. Vol. V, ii.
Platystoma turbinatum.
Trochonema tricarenatum.
Pal. Ohio, I,
Xenophora? antiqua. (Trochita antiqua, Meek.
VIII a
1 a.
Pal. Ohio
1 c
1 e
1 d
Cyrtoceras undulatum. (Gyroceras
VIII a.
Hall.
Cardiola speciosa.
Cypricardinia lamellosa
VIII a.
1 a.
1 b
Conocardium trigonale.
VIII. a.
Hall. 67.
VIII. a.
Cypricardinia indenta.
Solenomya (Janeia) vetusta, Meek
Orthoceras pelops, Hall.
Megambonia carduformis.
VIII. a.
Hall. 68.
1
Modiomorpha complanata
VIII a, c
Vol. 5, Pl. 33
Sanguinolites? sanduckiensis, Meek
VIII a
Meek
Pal. Ohio I, pl. 11.
Orthoceras profundum, Hall.

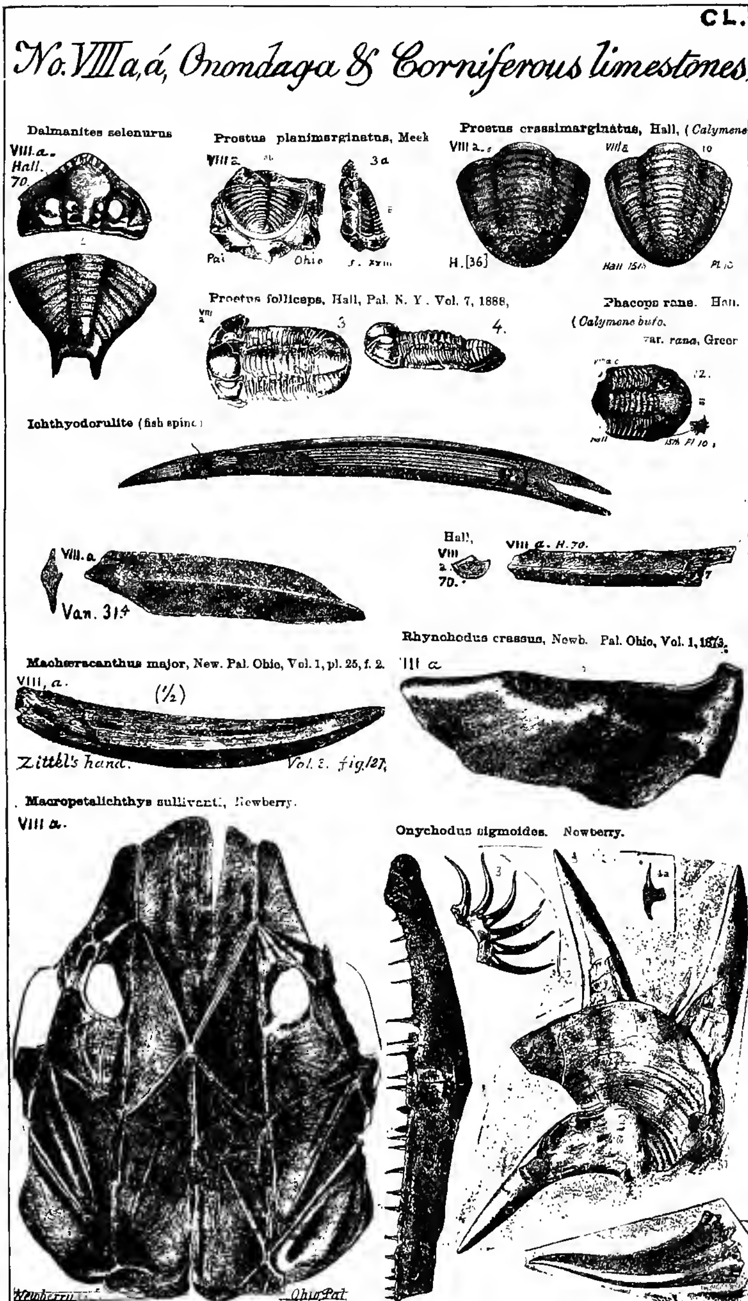
solid plates of limestone; as shown in the *Leroy quarries*, Genesee county, Western N. Y.*

The Leroy quarry Section, N. Y.

Limestone, grey, slaty or compact, fissured (two beds),	20''	48''
Limestone, grey, ... (two beds),	28'	
Hornstone, with little limestone, ...		8'
Limestone, ...		17''
Hornstone, ...		4''
Limestone, ...		10''
Hornstone, ...		14''
Limestone, grey, ...		18''
Hornstone, ...		3''
Limestone, ...		9''
Hornstone, ...		3''
Limestone, grey, compact, . .	24''	96'
Limestone, thinly laminated with fossils, . .	24'	
Limestone, compact, . . . with fossils,	24''	
Limestone, with *hornstone balls*, . . .	18'	
Limestone, . .	6'	
Hornstone, ...		4''
Limestone (two beds), ...		22''
Limestone, with *hornstone balls* (2 beds, *hornstone parting*), ...	38''	106''
Limestone (6 beds separated by *hornstone* layers),	72''	
Limestone, (2 beds; irregular *hornstone parting*),	26''	
Limestone thin bedded; many *hornstone balls; full of corals*		36''
Limestone; large *mixture of hornstone; some corals*,		120'
Limestone (2 beds), ...		20''
Badly exposed beds, with many *silicified corals*, standing out from the rough and ragged rock surfaces even more prominently than the hornstone which envelopes them.		288''
Hornstone layers, with some little lime, very rough,		
Onondago limestone, no fossils; 6 feet.		
Total, Corniferous formation, ...		71' 4'

It is to be noticed, (1) that hornstone layers (with a little lime) were (at Le Roy) deposited before the corals began to grow; (2) that the dead corals were dissolved and replaced by hornstone; (3) that hornstone balls and corals are to be found in the same bed; (4) that balls without corals, and corals without balls, occur in several beds; (5) that some beds are without either corals or balls; (6) that the sheets of hornstone alternating with sheets of limestone are

* Forty-five miles east of Buffalo, and 20 miles west of Rochester. See Hall's section, 1843, page 166.


CL.
No. VIII a, á, Onondaga & Corniferous limestones
Dalmanites selenurus
VIII. a. Hall. 70.
Proetus planimarginatus, Meek
VIII a
3 a
Pal
Ohio
Proetus crassimarginatus, Hall, (Calymene
VIII a.
VIII a
H. [36]
Proetus folliceps, Hall, Pal. N. Y. Vol. 7, 1888,
3
4.
Phacops rana. Hall.
(Calymene bufo.
var. rana, Green
Ichthyodorulite (fish spine)
VIII. a.
Van. 314
Hall,
VIII a.
70.
VIII a. H. 70.
Rhynchodus crassus, Newb. Pal. Ohio, Vol. 1, 1873.
Machæracanthus major, New. Pal. Ohio, Vol. 1, pl. 25, f. 2.
VIII, a.
(½)
Zittel's hand.
Vol. 2. fig. 27.
Macropetalichthys sullivanti, Newberry.
VIII a.
Onychodus sigmoides. Newberry.
3
4
4a
Newberry
Ohio Pal.

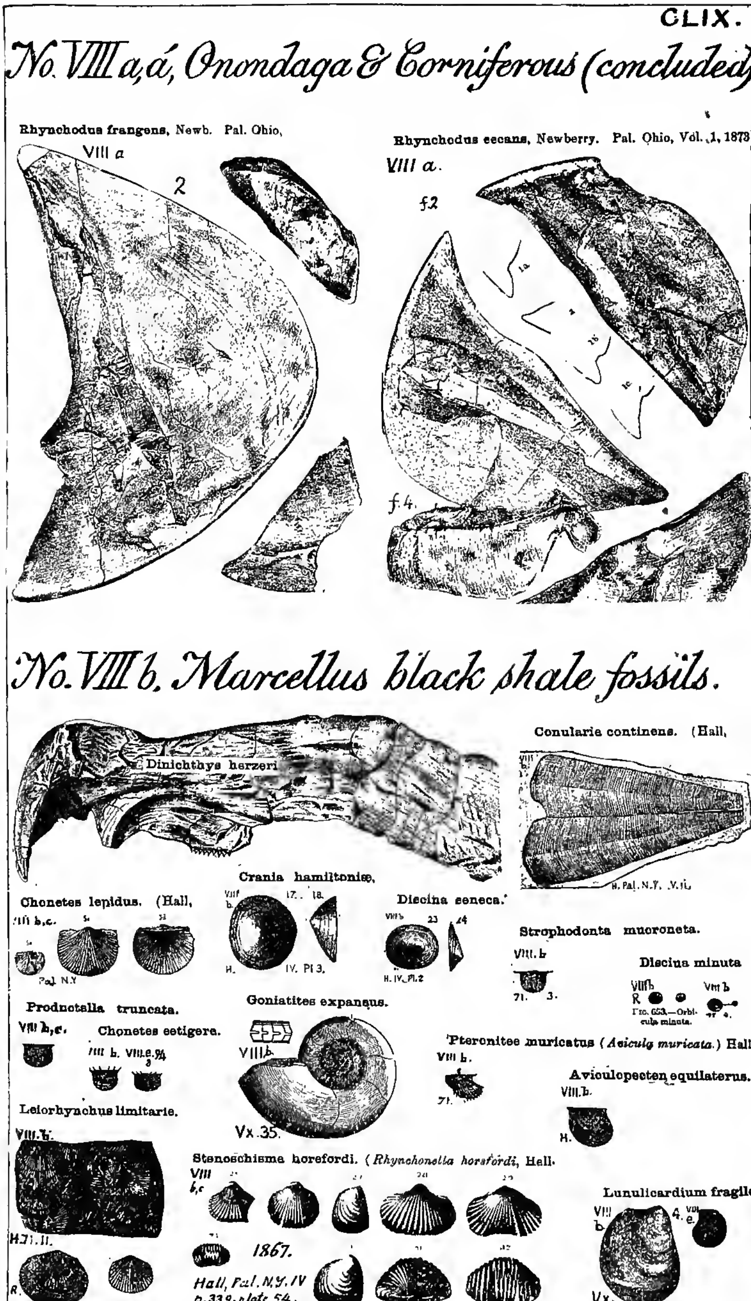
almost entirely confined to a 7 foot zone near the top; (7) that this zone of alternations is capped by 4 feet of common limestone, followed by black shale.

These noticeable facts are confusing; for, they permit two opposite hypotheses; that the sea water was loaded with silica, as well as with lime, and therefore prepared for the growth of corals; or (2) that the growth of coral itself, by some process of animal chemistry, caused the saturation of the seawater with silica, which silica was ready to take the place of the pure coral, or of the nearly pure lime mud, or any lime concretion in the impure lime muds, as soon as these were dissolved and a vacancy occured. Probably both these notions are correct, and that what we see is a complicated result of several processes carried on simultaneously during the Corniferous age; but these notions might be greatly modified by unexpected discoveries if quarry work were carried down some hundreds of feet beneath the present surface beyond the reach of rain water.

If some great river from Eastern Canada pouring into the Palæozoic sea quantities of *labradorite feldspar mud* the finest particles of which floated as far as Pennsylvania and were kept in continual suspension by the winds and waves, coral animals and shell fish then living must have appropriated the lime, and the silica set free must have been precipitated, partly as hornstone, partly in composition with the alumina in the undecomposed feldspar, as mud, blackened by the decayed soft tissues of the animals as they died.*

Our microscopic knowledge of the hornstone is not sufficient to confirm the suspicion that the hornstone balls, so irregular in shape as we shall see in describing the Delaware river outcrop, are fossil masses of the skeleton fibres of sponge-like animals secreting silica, like the flint balls of the Chalk; or masses of ancient species of diatomaceæ like

* We shall see that petroleum fills many of the hollow casts of the corals; and that it pervades and blackens the whole *Marcellus* formation. Where the limestones alternate with hornstone they are as black as the hornstone layers. This is the origin of the name Black Rock at the outlet of Lake Erie.


CLIX.
No. VIII a, á, Onondaga & Corniferous (concluded)
Rhynchodus frangens, Newb. Pal. Ohio,
VIII a
2
Rhynchodus secans, Newberry. Pal. Ohio, Vol. 1, 1873
VIII a.
f.2
f.4.
No. VIII b. Marcellus black shale fossils.
Dinichthys herzeri
Conularia continens. (Hall,
H. Pal. N.Y. V. II.
Crania hamiltoniæ,
IV. Pl 3.
Chonetes lepidus. (Hall,
Pal. N.Y.
Discina seneca.
H. IV. Pl. 2
Strophodonta mucronata.
VIII. b
Discina minuta
Fig. 653.—Orbicula minuta.
Productella truncata.
VIII b, c.
Goniatites expansus.
VIII b.
Vx. 35.
Chonetes setigera.
Pteronites muricatus (Avicula muricata.) Hall.
VIII b.
Aviculopecten equilaterus.
VIII. b.
Leiorhynchus limitaris.
VIII. b.
H. 71. II.
Stenoschisma horsfordi. (Rhynchonella horsfordi, Hall.
VIII b, c
1867.
Hall, Pal. N.Y. IV p. 339, plate 54.
Lunulicardium fragile
VIII b.
Vx.

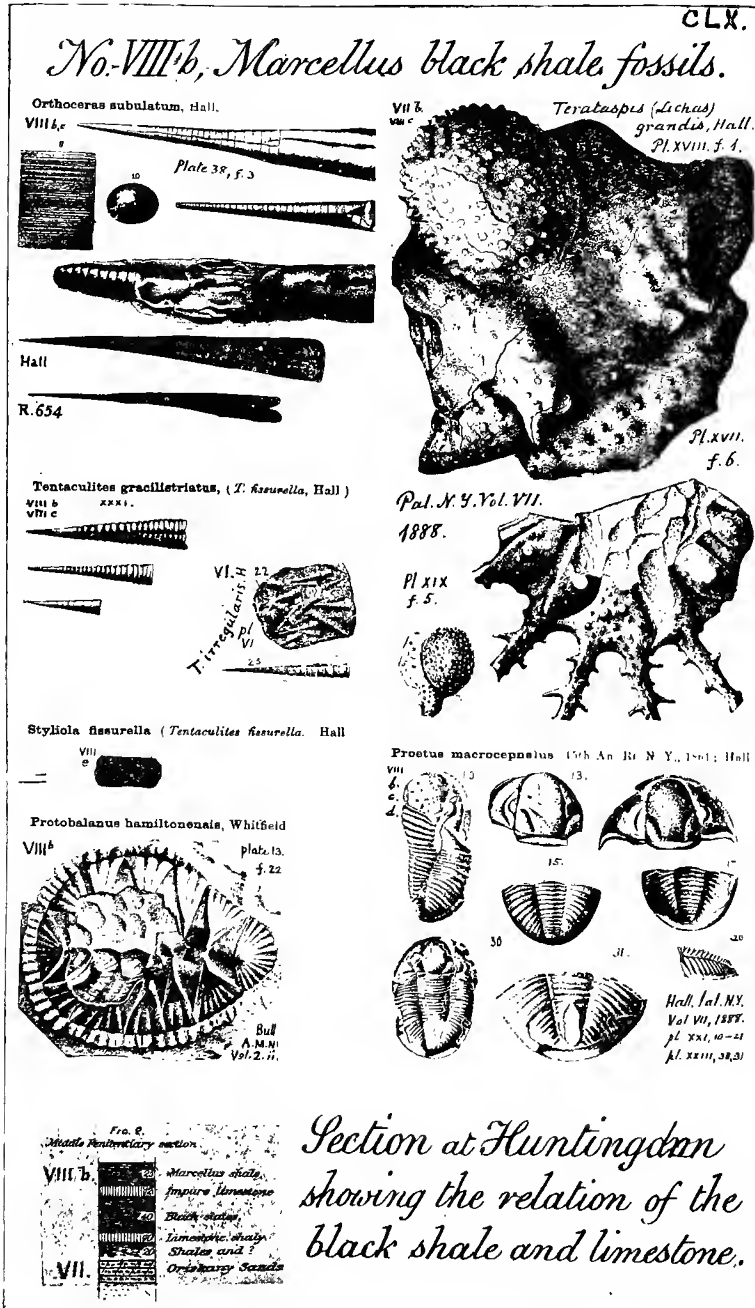
those which assist in making the oozy bottom of the ocean now.

The *Corniferous* (*upper division*) is not a coral formation like the preceding *Onondaga* (*lower* subdivisions); corals and crinoids in it are comparatively rare; it has indeed few fossils, and these are mostly *shells*. But some of its limestone layers look as if they had been made out of the meal of coral reefs, floated to a distance, and mixed with siliceous mud. In fact the *Corniferous lime beds* are distinguished from the *Onondaga lime beds* by the greater compactness of the rock, by the abundance of hornstone,* and by the general absence of *Favosites and crinoidal stems*. Their compactness make them good *building stone*, and readily dressing to a smooth face; the lower beds too dark for architectural beauty; the upper beds lighter in color, are so free from hornstone as to be extensively quarried for *lime burning*.†

At Vienna, Freedom and elsewhere the *triple division* described in the note is observable; but it cannot be said

* The layers of hornstone are irregular. The balls vary in number in every limestone bed; sometimes scattered sparsely through it; sometimes crowding it so full as to convert it almost into a hornstone bed; but still remaining separate enough to preserve their individuality, and weathering to a horrid rough mass wherever the intervening limestone has been dissolved away; so that the quarrymen nicknamed it "chawed rock."—At Vienna in Ontario county the lower twelve layers (or Onondaga) are almost all hornstone, rugged, worn by the water, and standing out in knobs. The middle beds are blue; weathering white, shaly, without hornstone, but containing innumerable *fossils almost too small to be seen*. The upper beds are compact, with hornstone, capped with lime shales. Where the hornstone abounds fossils are rare. This triple division is seen elsewhere but is not general. The *proportion of hornstone* varies at every locality, but some of the beds are sure to be largely composed of it, and in some places predominates in half the mass. Between LeRoy and Caledonia hundreds of acres paved with small angular pieces of broken *hornstone*, mixed with larger masses held together by the lime cement, were once accounted worthless, but now produce the finest crops, the stones making both a manure and a warm covering to the soil. The *hornstone* knobs are all cracked by the sun, receive water, which freezes and splits them into fragments. The rock is therefore one of the best *road-metal* that can be found.

† Two sets of vertical cleavage planes at right angles give a rare chance for easy and extensive quarrying. (See Prof. Hall's sketch of a Waterloo quarry on his page 161.) There are also great fissures, which let the surface water down, and sometimes become enlarged so as to engulf brooks, which issue in innumerable fine springs along the outcrop.


CLX.
No.-VIII'b, Marcellus black shale fossils.
Orthoceras subulatum, Hall.
VIII b,c
Plate 38, f. 3
Hall
R.654
Teratospis (Lichas) grandis, Hall.
Pl. XVIII. f. 1.
Pl. XVII. f. 6.
Pal. N. Y. Vol. VII. 1888.
Pl XIX f. 5.
Tentaculites gracilistriatus, (T. fissurella, Hall)
VIII b VIII c
T. irregularis. H
pl VI
Styliola fissurella (Tentaculites fissurella. Hall
Proetus macrocephalus
Protobalanus hamiltonensis, Whitfield
VIII b
plate 13. f. 22
Bull A.M.N Vol. 2. ii.
Hall. Pal. N.Y. Vol VII, 1888. pl. XXI, 10–21 pl. XXIII, 30, 31
Middle Penitentiary section
VIII. b.
Marcellus shale
Impure limestone
Black slates
Limestone shaly
Shales and ?
Oriskany Sands
VII.
Section at Huntingdon showing the relation of the black shale and limestone.

to characterize the formation as a whole; nor is the distinction in quality of rock between *Corniferous* and *Onondaga* really any greater than the distinctions visible in the body of the Corniferous itself. Even as to fossils, in some places *Favosites* and *Encrinal stems* may be found in its *middle beds;* but its *upper beds* have always a set of species of their own which are not known to have lived earlier or later in the region under review; for example the two trilobites *Dalmanites* (*Odontocephalus*) *selenurus* and *Prœtus* (*Calymene*) *crassimarginatus*.*—A *Cyrtoceras* in the upper grey quarry beds west of Waterloo, N. Y. often attains a great size.—Its most common brachiopod shells, in western New York, are: *Meristella* (*Atrypa*) *scitula*;† *Paracyclas* ‡ *elliptica;* *Chonetes* (*Strophomena*) *acutiradiatus;* § *Strophodonta* (*Strophomena*) *crenistria;* ‖ *Spirifera* (*Delthyris*) *duodenaria;*¶ *Conocardium* (*Pleurorhynchus*) *trigonale*. **—Besides these there lived also in western New York the large heart-shaped lamellibranch shell *Megambonia* (*Pterinea?*) *cardiiformis;*†† a straight spine-like pteropod shell, an inch long, *Tentaculites scalariformis;* ‡‡ a shell like a bear's claw, 1½ in. long, *Platyceras* (*Orthonychia*) *subrectum;* §§ a gasteropod, as big as a walnut, *Pleurotomaria* (*Enomphalus?*) *rotundus;* ‖‖ another like a liberty cap, an inch long, *Platyceras* (*Acroculia*) *erecta*. ¶¶

Fish-spines (*ichyodorulites*) have been found at several

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*The tail part of the body is often found and is typical of the formation also throughout Ohio, Indiana and Kentucky.—†Small prominent beak. ‡Because resembling a *Cyclas*.—§ Very abundant in the upper beds five miles east of Albany.—‖ Looks like seven or eight ruffles laid on one another, the edges projecting; lived on into Hamilton times.—¶ Very abundant but almost never perfect; differs from Conrad's *D. raricosta* (Vanuxem's *D. undulatus*).—** Differs from Hall's *P. cuneus* of the Schoharie grit. (Hall, 1843, p. 172.)—†† Perfect casts can be found, closely resembling one of the Oriskany species.—‡‡ The apparent rings around this beautiful little shell are in reality steps, like stories of a Dutch steeple, or like the tubes of a telescope. It looks exactly like the *Hudson river* (*No. III*) *tentaculite* of eastern New York; just as in England it is plentiful in the *Ludlow* and also in the *Caradoc* formations.—§§ Much like the *Platycerata* of the Lower Helderberg, No. VI.—‖‖ Mouth whorl much expanded; taper rapid.—¶¶ Not rare. Some have the trumpet end not so closely inwound. (Hall's descriptions.)

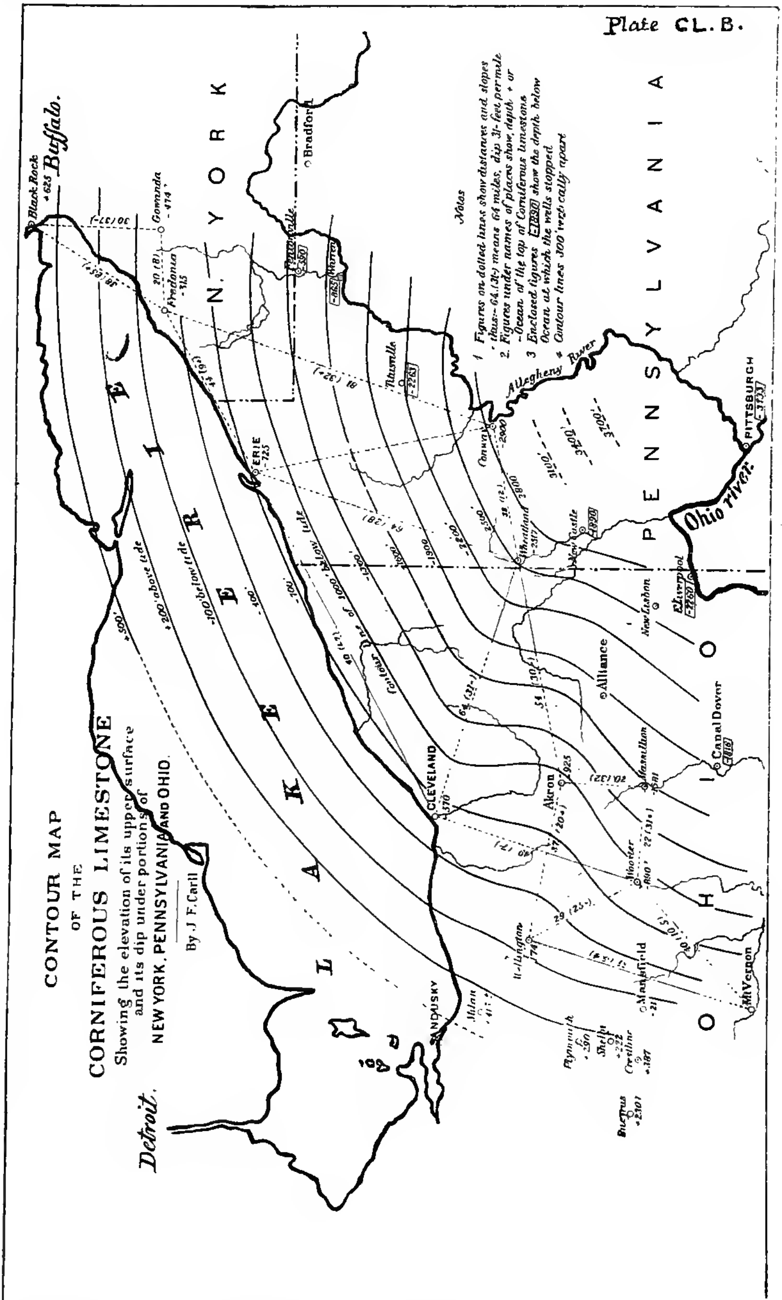
Plate CL. B.
CONTOUR MAP
OF THE
CORNIFEROUS LIMESTONE
Showing the elevation of its upper surface and its dip under portions of
NEW YORK, PENNSYLVANIA AND OHIO.
By J. F. Carll
Notes
1 Figures on dotted lines show distances and slopes thus:- 64 (31-) means 64 miles, dip 31 feet per mile
2 Figures under names of places show depth + or - Ocean of the top of Corniferous limestone
3 Enclosed figures show the depth below Ocean at which the wells stopped
4 Contour lines 300' vertically apart
N. YORK
PENNSYLVANIA
OHIO
LAKE ERIE
Buffalo.
Black Rock
Gowanda
Fredonia
Bradford
Titusville
ERIE
CLEVELAND
Akron
Alliance
Canal Dover
Massillon
Wooster
Mansfield
Mt Vernon
Wellington
New Lisbon
E. Liverpool
New Castle
Wheatland
PITTSBURGH
Allegheny River
Ohio river
SANDUSKY
Detroit.
+200' above tide
-100' below tide
Contour line of 1000' below tide

places in western New York. One, figured by Hall (1843, p. 174) 5½ inches long, giving a good idea of their aspect as they lie in the strata. They belong to different species of fish, and vary in size, shape and markings. One from the Waterloo quarries, more than 8 inches long, is curved almost to a semi-circle, and its surface is smooth, except a sharp ridge along the center line.*

In Central New York, Vanuxem found the following to be the prevaling fossil forms in the formation.

In the upper beds in Seneca county (but not to the east or west of that county) a very little shell is extraordinarily abundant which he called *Strophomena lineata*, but it is now known as *Chonetes lineata*.†

Dalmanites selenurus is found at the Springport quarries in the *Seneca* limestone beds; is found in the underlying upper Corniferous flint beds at the Auburn quarries; and is plentiful in these upper "*Selenurus* beds" in the Schoharie region of the Mohawk valley. Its heads and tails (always

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*Fish beds in VIIIa.—Dr. Newberry's most interesting description of the fish beds of the *Corniferous limestone* in Ohio (on page 29, 30 of Monogram XVI of the U. S. Geological Survey, 1889, "The Palæozoic Fishes of North America") includes a novel and probably true theory of their origin, accounting for the vast number of the remains, their fragmentary and macerated appearance, and their deposit in thin layers over a large area with no admixture of sandy and muddy detritus.

The bone bed discovered by W. I. H. Klippart in the upper part of the formation, a few miles north of Columbus, is only from two to four inches thick; extends over several square miles; is almost entirely composed of fragments of plates, teeth, spines, and dermal tubercles of Ganoids, Placoderms, and Elasmobranch fishes so broken and worn as to make their study difficult; but many entire teeth and dermal tubercles, all detached and scattered, mostly worn and rounded, as if beach-worn, but unmingled with either sand or pebbles; apparently deposited in deep water; and probably the indigestable excrements of larger animals feeding on the fishes of a lagoon, or bay, enclosed among coral reefs.

Another quite similar fish bed, of the same age, at Mt. Vernon, Ind., contains many of the same species. (See further remarks in Dictionary of Fossils, P. 4, under the head of *Sharks*.)

†It seems to have had a sudden and extraordinary growth at that time in that part of the sea bed. It had existed previously, but is extremely rare in the underlying Corniferous beds. It is not to be found in the *Marcellus formation*, but it must have continued to live in other regions of the sea bottom, for it reappears in great numbers in the subsequent Hamilton age. See Vanuxem's little dissertation on characteristic fossils, pp. 144, 145.

separate) are also scattered through the whole Corniferous formation in western New York. It must have been about 4″ long.

Gyroceras (*Cyrtoceras*) *trivolve* is the next most characteristic shell of middle and eastern New York. There are four or five of these ram's horn cephalopod shells in the formation, varying in diameter from 4 to 7 inches, one of which, *Gyroceras undulatum*, has been collected at various quarries in western New York. — *Strophomena rhombaidalis* is specially characteristic of this formation,— *Strophomena depressa* is about the same size, but with only about 8 ribs instead of about 18 ribs.—*Orthis lenticularis* occurs in eastern, but not in western New York.— *Atrypa reticularis* (*prisca*) is one of the most abundant Corniferous shells of western New York, with its long beak, almost pentagonal outline, strong lines of growth, and radiating striæ.—Fish spines are also figured by Vanuxem on pages 139 and 145 of his report of 1843, one of them 7¼ in. long by 1⅛ in. wide, curved and pointed.

At Cherry Valley, the head of the Delaware river, the *Corniferous* limestone with the underlying *Onondaga* is 60′ to 80′ thick, making several terraces through the village. Here a great stretch of it is bared showing glacial scratches and grooves. Quarries show its characteristic vertical jointage, which is most regular smooth and straight where the flints exist.†

† The *jointed* condition has been produced probably by repeated earthquakes. Its date is unknown. Howland's quarry south of Springport, Cayuga county, N. Y. affords a slight indication of it. All along the New York outcrop the southerly dip is nearly horizontal, 25′ to 3′ per mile ; here the strata are tilted to 29° ; *and yet the joints are as vertical here as elsewhere.* If the joints were older than the dip they ought here to stand 20° to the northward ; therefore they have been produced since the tilting of the beds took place. Vanuxem gives (p. 144) a picture of the quarry to show the tilted beds and vertical joints ; but it is not sufficiently well drawn to serve as a proof of the exactness of the statement.—The layers make excellant flagging. In Oneida county, near Cassville, Town's quarry is a good place to collect *Gyroceras trivolve*, both in the lower beds without flint and in the upper flint beds. The formation is well exposed at Oneida Falls ; also at West-hill, south of Syracuse ; also in the hillside east of Marcellus in Onondaga county. It is extensively quarried in Cayuga county, at Auburn and Springport, and in all of them the flint beds make the capstone of

The outcrop of the Corniferous formation can be followed from Leesville, Cobleskill and Schoharie eastward to the top of the Helderberg; thence southeast and south at the foot of the Catskill mountains to Esopus falls ; patches of it being seen occasionally among the upheaved masses about Kingston, Hurley, Bridgeport, Rochester, etc. (Mather's report, p. 337.) Its outcrop runs southwest through the middle of Ulster, the southern border of Sullivan, and the western corner of Orange, to the Delaware river at Carpenter's Point, or Port Jervis, where it may be said to enter Pennsylvania along its southernmost outcrop.

All that has been given in this chapter has been a necessary preparation for its description in Pennsylvania in the next chapter.

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the quarries. In one of these Auburn quarries (Buhr's) there are nine beds of rock ; the fourth from the bottom (3′ thick) having a peculiar diagonal lamination (at an angle of 35° to the bed planes); the ninth shows eight ranges of flint balls, in four pairs, with greater spaces between the several pairs of ranges. The lower beds are most shaly, as elsewhere, and most fossiliferous, also as usual elsewhere.

Chapter LXXXIII.

No. VIIIa. The Corniferous in Pennsylvania.

In describing the Upper Helderberg in Pennsylvania no distinction will be made between the Onondaga and Corniferous subdivisions, both being included under the latter name. Nor is it necessary to discuss the lower limit of the Devonian system of Europe further than has already been done in preceding pages. In view of the extreme difficulty which British geologists have experienced in systematizing the rocks of North and South Devonshire, and in collocating them with the Devonians of Scotland and other European countries, it seems a work of supererogation to try to put definite limits to the system in America. No advantages accrue to American geologists from such discussions, and it is a matter of indifference whether the system be made to commence with the base of the Oriskany, with the Caudagalla grit, with the Onondaga limestone, or with the Marcellus black shale. I hold therefore to the classical numbering of the formations by the first Pennsylvania survey, which grouped the whole series from the top of the Oriskany No. VII, to the bottom of the Catskill as No. VIII, and the Catskill as No. IX.

No. VIIIa. The Corniferous on the Delaware.

The corner stone of the three great States of New York, New Jersey and Pennsylvania stands at the western point of a *Corniferous limestone* ridge, only a few rods wide, which for about a mile prevents the two rivers *Neversink* and *Delaware* from uniting their streams of water. This is *Carpenter's Point*, one mile south of the large town of Port Jervis on the New York bank, and Matamoras on the Pennsylvania side of the Delaware. The river here changes its general S. 30° E. course to one S. 65° W., washing and exposing the *Corniferous* beds which dip toward and under its channel 20° (N. W.).

The whole formation is about 250′ thick, and consists of successive layers of *dark gray limestone*, some of which are only a foot thick, others ten feet thick, in which are embedded multitudes of *black flint nodules*, varying in size from an inch to a foot in diameter, of no regular shape, but usually longer than thick, and arranged parallel to the planes of bedding. *

These flints are not all silex; some of them contain enough lime to be destroyed by the weather, becoming spongy and rotten, and then slowly removed. The rock in which they are embedded is on the contrary a fairly pure *non-magnesian limestone.* † They are in fact segregations of silica in and around fossil animals, shells, crinoids, corals, etc., more or less distinct remains of which can be found within them.

Attempts have been made in Monroe county to quarry the limestone strata for lime burning, but the flints melted into a silicious slag so that much of the lime would not slack. Some of the beds are much more cherty than others, the top layers of the formation containing many more nodules than those below them. *Fossil shells* and *corals* are also much more abundant in the upper layers. *No fish remains have been noticed.* ‡

*These flints are the terror of bathers in the river, for their limestone matrix dissolves away from around them, leaving their sharp, black, dagger-like points projecting sometimes six or eight inches above the rock, which, whether under water or in the hillside, has a rough and most forbidding aspect. No part of the formation seems to be free from them, and in places they make up nearly half of the stratified mass.

†Two *limerock* specimens (from E. Stroudsburg and from H. H. Campbell's land) yielded to analysis:—Carbonate of lime, 89.0, 83.7; carb. magnesia, 0.9, 1.2; ox. iron and alumina, 0.4, 0.5; sulpher, 0.056, 0.025; phosphorus, 0.012, 0.070; insoluble residue, 19.9, 14.5. An *average* specimen of *flint* gave:—*Carbonate of lime*, 20.267; carb. mag., 0.681; ox. iron and alum., 0.640; insoluble residue, 77.560. This *residue* gave:—*Silica*, 72.430; ox. iron and alum, 0.770; lime, 0.210; magnesia, 0.195=73.605 (G6, 118; B). Many nodules contain less, and some more lime than is here shown, judging by the different degrees of readiness with which they disintegrate under the weather.

‡The neighborhood of Stroudsburg is about the best collecting ground for fossils, especially the vertical outcrops on the south bank of McMichael's

From Carpenter's Point to Walpack Bend the formation runs through New Jersey, the river, in its snake-like progress down the Marcellus Valley striking the top of the formation with its southern curves many times, and at last breaking through it at the Bend.

From Walpack Bend to Stroudsburg the Marcellus Valley is at first occupied by Pond creek, and the *Corniferous limestone* makes a conspicuous outcrop all along the northern foot of the Walpack Ridge of *Caudagalli grit* (described in the chapter on No. VII page ——, above, to within half a mile of Broadhead's creek. Here it is zigzaged southward three miles over three anticlinal rolls, and then assumes the same position at the north foot of Godfrey's ridge, and runs on westward, up the valley (mostly on the south side) of McMichael's creek to Kellersville, growing thinner and thinner, and disappearing from observation in Hamilton township. *

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creek, east of the road leading over Godfrey's ridge to the Delaware Water Gap. Here can be got good specimens of *Phacops bufo*, a trilobite; *Atrypa articularis*, and *Atrypa spinosa; Strophomena rhomboidalis* and *Strophomena perplana; Conocardium trigonale; Cyrtoceras undulatum*, and species of *Platyceras*: two corals, *Zaphrentis rafinesquii*, and a *Cyathophyllum;* many species of *Orthis*, and other forms not identified. (G6,121.)

* From Walpack Bend to Stroudsburg the northern edge of its outcrop coincides closely with the turnpike. The dip northward is always steep; the width of the outcrop seldom more than 300 yards, the thickness of the formation approaching Stroudsburg about 200 feet. Where it does not project in bold and rugged cliffs it covers the soil with enormous masses of rock. Cliffs 10 to 20 feet high succeed each other rapidly in a line high up along the slope of the ridge. Along McMichael's creek also its massive strata keep themselves almost constantly in sight on the hillside as far west as the Bull Run school house, within 1½ miles of the Hamilton-Ross township line. Here the formation is thin and sandy, but full of chert balls.

A few details of *Corniferous* exposures will suffice. Along the Milford-Stroudsburg pike, west of the Bushkill, the Corniferous touches the road at only two points—just south of Shoemaker's corners, and near S. C. Angle's, on the township line, near Broadhead's creek. The outcrop varies on the ridge slope from ¼ to ¾ of a mile, according to the height to which its bottom beds have escaped erosion. Black chert balls, from the size of a hen's egg to a foot in diameter, fill the strata. There is a small *quarry* south of Echo Lake, in the top layers, which are very *fossiliferous*. Dips are very variable (from 30° to 0°) in short distances, sometimes *reversing to a south dip*, causing vertical ledges 10′ to 15′ high; immense blocks heaped together, well seen on the road which runs south from the pike at A. Miller's. Here many acres are covered with huge, rough blocks and long cliffs. *Glacial*

No. VIII a. Corniferous on the Lehigh.

West of Stroudsburg nothing is seen of it until approaching the Lehigh river, where it consists of only 5′ of *limestone full of flint nodules*, and 20′ of *underlying hydraulic*

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scratches are not often seen on the lime rock, but are well *preserved on the ground-off surfaces of the flint balls.*

In Smithfield township the rock surfaces are everywhere *ice-scored.* On the road south from the pike at S. Marsh's (Stroud township line), and on the hill south of B. Morgan's, is a narrow *trough of Corniferous* preserved along the crest of the *Caudagalli* hill. In the next little basin to the south, where the dip steepens to 10°, 15°, 20° (S.) the *Corniferous* is again preserved. *Immense blocks* of it (20′x20′x30′) cover the surface, apparently *moved by the ice-sheet* from the northern outcrops; glacial *scratches* ¾ m. S. E. of B. Morgan's, running S. 40° W., and the chert masses being *ground off smooth* with the face of the limestone rock in which they are embedded (600′ A. T.). *Isolated blocks and patches* occur lying on the *Caudagalli* hill surface, showing how the *Corniferous* has been removed, a good example being the ledge of rock, 50′ high, along the road leading S. E. from the pike at the township line. The destruction of the formation is shown also by the preponderance of its fragments over those of *Caudagalli* and *Oriskany* in the great terrace of drift (100′ high) on the north bank of Broadhead's creek south of Stroudsburg.

From Marshall's creek P. O. the pike runs diagonally (westward) across the *Corniferous belt* (here ½ mile wide) from its northern to its southern edge and south of it. It was formerly here quarried and burned with little success, although attempts were made to eliminate the flints.

The *contact of Corniferous upon Caudagalli* can be seen in the bed of Broadhead's Creek, just below the Stroud county line, south of Stroudsburg, both dipping 17° (S. S. E.) into the trough which carries the Corniferous *east* to Buttermilk falls on Marshall's creek; and *west* to the cliff where the whole formation is exposed to a height of 250′ above the stream; being itself 200′ in thickness.

Broadhead's creek strikes the foot of Godfrey's ridge; turns at a right angle and flows E. N. E. 1½ miles; then turns again at a right angle and gaps the ridge. Here it exposes 100′ of *Corniferous strata* turned up beyond the vertical. Its lower beds also make a series of cascades; being hard, *silicious lime rock, filled with flints.*

The East Stroudsburg anticlinal in Stroud township arches the *Corniferous;* and down a trough of it McMichael's creek flows from the west. The arch makes a low ridge which is cut by a bend in the creek. At East Stroudsburg the D. L. W. RR. cut exposes the whole formation, *turned over* so as to dip 65° (S. E.) then vertical and then 20° to 25° S. E. The rock is dark bluish-grey, quite *fossiliferous* in places, and *filled with black flints from top to bottom.* The crest of the arch is *caudagalli.* The strata in the south leg of the arch are *honeycombed* with holes from which almost all the *flints have been weathered out.* The whole cut is 700′ long, 300′ of which are through Corniferous in the north leg of the arch. West of the cut Broadhead's creek exposes the arch of Corniferous in great black-looking cliffs. The arch runs west through the center of the wide level bottom south of *limestone beds.* Here in Rocky Ridge the cherty limestone, 5′ thick, is precisely like that which is 200′ thick at Stroudsburg, and 250′ thick at Carpenter's Point. There

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Stroudsburg; and in a steep cliff faces southward the top layers of the formation hold many *fossil shells.*

In the N. Y. S. W. RR. cut through this arch, along the west of Broadhead's creek the demoralizing effect upon the rock of a few feet of overlying drift deserves careful study. Just north of this, the top layers can be seen dipping 25° (N. N. W.) under blue-gray *Marcellus shale.*

The *contact* can again be seen where the arch crosses the road between Col. Norton's and the McMichael's creek bridge. There is here a concealed interval of less than 4 feet between limestone and the overlying shale, both being ice polished and scratched. Just south of this the upper beds in a cliff are quite *fossiliferous.*

The arch of *Corniferous* is finely shown near Huston's (2½ miles west of Stroudsburg) the multitudes of flints causing the lime quarry to be abandoned; their ends have been ground off smooth by ice moving S. 50° W.

Another arch, crossing Broadhead's creek 1½ miles above Stroudsburg, finely exposes the limestone beds in a natural mill dam of 10′ fall, dipping 16° (S. S. E.) and quite *fossiliferous.* About 300 yards above this, in a cliff, the N. N. W. dipping layers, 1′ to 2′ thick, hold many *fossil Corals, Crinoids, shells*, among vast numbers of flint, which made a *lime quarry* here a failure. This arch runs east between Posten S. H. No. 4, and the Cemetery, where is a cliff 75′ high of flat *Corniferous* layers, soon dipping 20° (N.) under *Marcellus shale;* the south dips make a bluff where the pike crosses the railroad; in the cut south of Sambo creek *the layers are half flint;* west of Broadhead's creek this arch sinks and carries the formation down beneath the broad outspread of *Marcellus.*

In the *fourth terrace* at the north line of the borough Stroudsburg great numbers of *immense blocks* of *Corniferous limestone* and *Hamilton sandstone* may be seen, one of them so large that it may at first sight be taken for a ledge of the mother rock,

On McMichael's creek *Corniferous* limestone beds sink 100′ south of the Stroudsburg iron bridge, where the *Marcellus* blue gray shales dip 27° (N. N. W.); concealed interval only 40 or 45′.

The East Stroudsburg anticlinal enters *Hamilton township* just below Kunkleville; McMichael's creek here cuts southward through an arch of *Corniferous limestone* supported by *Caudagalli grit.* At this fine exposure the (15° to 20°) north dips extend along the banks 200′ yards (to above the bridge); making the whole formation 150′ or possibly 200 thick. The layers are flinty, and few of them fit for lime burning.—Westward runs a long uninterrupted line of rock ledges; quarried at the road forks next west from W. Bittenbender's; *full of black flints.*—A mile west of the creek a bluff 100′ high dips 25° to 30° (N. N. W.) from the arch.—Half a mile south of Kellerville (W. Benzonis) ice has smoothed a large area, *planing down the flints; rock quite sandy*, with little lime in it; *formation thin;* dip 25° (N. N. W.); arches southward over the *Caudagalli* ridge, and descends (16°, S. E. S.) at G. Erdman's to make a basin at the foot of Godfrey's ridge; rises to the surface at A. Meitzell's.

Here the *Corniferous strata* are so *sandy* that the flints in it do not sugcan be no doubt of the identity of the *Corniferous formation*, and it is probable that a careful search for it along Frantz's creek in Carbon and Monroe counties would show its continuity the whole distance between the Delaware and Lehigh Water Gaps at the north foot of the *Oriskany-Caudagalli* ridge. How much further southwest toward the Schuylkill it extends is not known. Its presence on the Lehigh would not have been suspected but for its exposure at the *hydraulic cement quarry* near the *paint tunnel* at Hazardville.

The cement layers, 20′ thick, make superior *hydraulic lime;* all the masonry of the Lehigh canal was laid with it half a century ago, and it has stood well. These must be considered the lower layers of the *Corniferous limestone*, although they contain no flints; but are a silico-argillaceous limestone, soft in texture and seldom exposed upon the surface of the ground.

Under the cement beds lies a bed of shale, one or two feet thick, full of concretionary masses of *iron pyrites*. At the outcrop this bed is weathered into a *brown hematite iron ore;* and the drainage from the bed makes small *iron ore bogs* along the north slope of Stony ridge. It is burnt, ground and sifted, and sold as a cheap, durable, dull red *paint*.

Under the paint-bed lies a bed of *clay* varying in thickness from 3 to 8 feet; the equivalent of a bed occupying the same position in Mifflin and Juniata counties. (See Report F, ———.)

Under this lies the *Oriskany sandstone;* consequently, the *Caudagalli* formation is represented by the clay, or was never deposited in this region, although it is so thick a formation twenty miles distant northeastward.

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gest a relationship to limestone; and this is the last place going west where it has been recognized; although there may be parts of its long outcrop between here and the Lehigh river where it might perhaps present itself feebly as a *limestone formation*.

*The Paint Ore Bed and Mines.**

Plates CLII, CLIII, CLIV on p. 1068, &c. show the run of the outcrop across the Lehigh river in southern Carbon county, and the locations of the Prince Manufacturing Co.'s mines Nos. 2, 3, 4, 5, 6 and 7; the Rutherford and Barclay slope and abandoned shafts and tunnel at and west from Millport; as well as the cement quarries and limestone quarry opposite the gap.†

On plate CLIV can be seen a columnar section of the measures, cut in the Ziegenfuss tunnel, viz: Marcellus slate 593 feet visible; under which, Onondaga? cement beds, 45′; Paint ore bed, 2′ 10″; Clay, 6′; lying directly upon Oriskany coarse sand rock and fine conglomerate beds, 152′; Cherty calcareous sandstone beds, 47′ (enclosing a bed of

* In 1856 Mr. Prince's mill on Big creek was set to grind the ore from the first mine opened, the B. George mine (now P. M. Co.'s No. 4) 1¾ m. E. of Bowmansville, and it was sold for $150 a ton at Weissport. H. Bowman organized the Carbon Metallic Paint Co. Then Mr. Lawrence organized the Lawrence M. P. Co. Other manufacturers were: A. R. Bass (Standard paint); A. Reiach (Lehigh metallic paint); M. L. Smith (mill in the gap); S. Snyder; Prince M. Co.; and Rutherford and Barclay. In 1886 only the Prince mills at Bowmansville and Rutherford mill at Lehigh Gap were going. (F. A. Hill's report.) The present state of the mines, kilns and mills may be known by consulting a paper entitled *The Paint Ore Mines at Lehigh Gap*, by Conrad E. Hesse, Mt. Carmel, Pa., published in the Trans. Amer. Inst. M. E. New York meeting, 1890; in which a plate shows the method of working the Rutherford and Barclay mine; another, gives a vertical section of the measures from gangway to surface; and a third, two sections and front view of the kiln in use by that company.

† These plates are copies (on half scale) of portions of Mr. Hill's long map published with his report on the Metallic Paint Ores along the Lehigh river, in the Annual Report of the Survey for 1886, part IV, pages 1386 to 1408, where the history and methods of the paint ore mining, the chemical composition, preparation, shipment, use, extent of market, and probable quantity of the paint ore are separately treated.

The title Marcellus ore, on the plates is, as I think, a misnomer dating from 1858, when M. R. Prince in exploring the Marcellus shale belt for beds of roofing slate good enough to compete with the Slatington beds of III down the river discovered the paint ore bed clearly above the Oriskany and so near the bottom of the Marcellus, and to suggest a geological connection with the Marcellus iron ore beds of the Lewistown valley on the Juniata river. But the Cement beds above the ore are of Upper Helderberg (Onondago or Corniferous) age; and the paint ore may be more reasonably referred to the Oriskany iron ore beds of the Aughwick valley in Huntingdon county and the great ore beds of Virginia.

iron ore, underlaid by shales and sandstones partially concealed, 140′.

At the Rutherford tunnel mine the ore bed varies from 6 inches to 6 feet ; covered by six inches of blue clay under the cement layers ; and underlaid by six feet of yellow clay over Oriskany sandstone.* The bluish gray ore looks like a very hard compact limestone ; is of lighter color in its upper plies, as if mixed with cement ; has in various places clay and slate partings.† Toward the surface outcrop the bed is decomposed and turned to gossan (brown hematite), and occasionally the hard ore plies in the workings are separated by layers of brown hematite‡ Large pieces of ore show a decided cleavage.

Mr. Hill's description of the ore is :—dull-blue, arenaceous, more or less pyritous, magnetic, and without the least appearance of an ore from which paint could be made.

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† East of the shaft the measures are overthrown (79°, S.) so that the Oriskany is the hanging wall of the mine. At the tunnel the dip is normal (40°, N.) The bed is much faulted. A diagonal N. E. fault near the river throws it 200′.—The thickness given in the text was reported to Mr. Hesse ; but Mr. Hill reports (p. 1389) an average of only 2′. He saw it in the Snyder shaft at one place only 6 in. and at no place did he see the bed more than 3′ 7″; but miners told him that in the Bass shaft, E. of Millport it became 5 feet, probably counting in the clay.

‡At the Rutherford shaft a section of it reads (upwards) : Sandstone, clay, *ore*, slate, *ore*, clay, *ore*, clay, *ore*, slate, *ore*, cement, slate. The partings however pinch out, letting the ore-plies come together. Mr. Hill's numerous cross sections show its variability : Mine No. 2, E. of Millport : Cement 1′, slate 6″, *ore* 4′, clay 7′ sandstone.—Cement ; clay 7′, *ore* 6′, clay 7′, sandstone.—Section fifty west of the last one : Cement, blue clay 3″, blue slate 7″, *ore* 2′, clay 7′, sandstone.—Snyder property line, at the face of same gangway : Cement, blue clay 3″, blue slate 7″, *ore* 5″, slate 3″, *ore* 10″, slate, clay, sandstone.—Mine No. 3 : Cement 40′, clay 3′ , *ore* 6″, slate 7″, ore 22″, slate 9″, clay 6″, sandstone.—Cement, soft clay 2″, *ore* 4″, slate 4″, hard clay 4′ , *ore* 15″ soft slate 4″, clay 4′.—Cement, clay 3″, *ore* 6″, blue slate 3″, *ore* 13″, blue clay 2″, clay and slate.—Mine No. 4 : Cement, blue clay 6″, *ore* 12″, soft slate 3″, *ore* 6″, soft slate 4″, clay and slate.—Mine No. 5 : Cement 4′ , clay 58″, *ore* 18″, clay 52″.—Cement, clay 4″, *ore* 24″, slate 14″, slate 3′ 8″, clay and soft slate.—Mine No. 6 : Cement, clay 4″, *ore* 3′ 7″, slate and clay 5′ 6″, sandstone.—Mine No. 7 : Cement, blue clay 7″, ore 7″, blue clay 3″, *ore* 14″, blue clay 21″, yellow clay 18″, sandstone.—Bowman mine ; Cement, blue clay 6″, *ore* 13″, clay and slate 13″, *ore* 6″, clay.

§ Driving the breasts up to the air the ore is found in half decomposed rounded masses (bomb shells) covered with iron oxide surrounded by a bluish clay.

Its chemical composition is expressed in a rather vague and unsatisfactory manner by Mr. McCreath's analysis of a sample from the mixed stock of the P. M. Co. which of coarse leaves the irregularities of the run of the bed quite unknown. An analysis of the paint made at the same time in the Laboratory of the Survey is given in parentheses :—Metallic iron, 34.6 (28.9); metallic manganese, 0.929 (0.983); alumina, 5.5 (10.6); lime, 3.5 (3.0); magnesia, 1.08 (2.03); sulphur, 0.674 (0.774); phosphorus, 0.018 (0.060); silica, 16.2 (37.8); loss on roasting, 24.35 (2.68).*

From the Lehigh Water Gap westward No. VIII*a* has not been well studied, and the limestone beds seen near Swatara Gap do not appear in the Susquehanna Gap above Harrisburg; but the outcrop appears and increases in Perry county as will be shown directly.

VIIIa on the Selinsgrove anticlinal in Northumberland and Snyder counties.

On the Susquehanna river near Selinsgrove the *Corniferous limestone* is brought to the surface by the two anticlinals at Georgetown, at the south end of Northumberland; by the Selinsgrove anticlinal; by the Montour anticlinal; by the Milton anticlinal; and by the Bald Eagle anticlinal at Muncy in Lycoming county; as described in previous chapters. We have therefore a fair opportunity to study its variable character,—quite as variable as its character along the Delaware river outcrop; for, it is 75′ thick at

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*The *decrease* in iron in the paint, and the *excessive increase* of alumina and silica show that the paint is not made by merely roasting the ore, but mixing some foreign red clay with the roasted ore. The sulphur is partially retained in the roasted ore perhaps by the presence of lime. In the raw ore the elements exist for the most part as carbonates. But no carbonic acid shows in the paint. (McCreath's notes.)

The paint is of great value to manufacturers of linoleums and oil-cloths. It is used for protecting iron railroad bridges against weather decay; steam and flange pipe joints; government shot and shell, gasholders, oil and water tanks, sea side houses, canvas tents, tin roofing, and ship bottoms. It is so fine that seven pounds of it in a gallon of raw linseed oil will cover 500 square feet of surface, hardening under water and not fading or scaling. Its market seems universal. (Hill's report.) For paints made from pulverized bessemer and other iron slags see a valuable illustrated paper by Axil Sahlin, M. E. in Trans. A. T. M. E. Oct. 1891.

Georgetown, 65′ thick at Selinsgrove, and scarcely recognizable along Montour's ridge.

It is the *Selinsgrove lower limestone* of Report G7 (finely exposed along the N. C. RR. just below Selinsgrove station); a series of hard, light grey, rather impure limestone layers (*without chert balls*) measuring from 1′ to 3′ in thickness each; separated by thin partings of grey shale; the whole section measuring 65′ (G7, 360).

Only one characteristic New York *Corniferous fossil* is found,—*Leptocœlia acutiplicata*, which in the railroad section below Selinsgrove occurs in large numbers in a layer of shale 15′ above the formation,—mixed with N. Y. *Hamilton shells: Ambocoelia umbonata* (still more abundant); and with *Strophemena rhomboidalis*, a *Pleurotomaria;* and a *Zaphrentis*, in less numbers.*

Some layers were once burned for lime 2½ miles north of the Selinsgrove Junction, and are sufficiently pure for that purpose. It is evidently a limestone formation; and there is no necessity for considering it an extension of those *Marcellus lower grey shales* which are 400′ to 500′ thick on the Delaware river.†

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* I can see no reason for repudiating this limestone formation as *Corniferous* because it shows only one Corniferous fossil shell, and no flint balls. Its stratigraphical position is exactly correct and must decide its name. It immediately underlies the well defined *Marcellus black slate* formation, here 300′ thick, pyritous, concretionary, and fossiliferous, as will be shown hereafter. It also overlies what there is no better reason for doubting to be *Caudagalli* grey *non-fossiliferous* shales (with a few thin bastard limestone layers in the uppermost 35′) 140′ thick, resting directly on well marked *Oriskany sandstone.* What better proof could we have for its *Corniferous identity as a deposit?*—It emerges from the railroad bed about half a mile below Selinsgrove Junction, and rises on the first or smaller arch up into a great cliff overhanging, the left (E.) bank of the river; its base on the crest of this arch is 140′ above the water level; then sinks (northward) beneath the Junction (G7, 362). Its rise upon the second or larger arch is concealed, the Oriskany coming up with a steep (S.) dip a mile above the Junction; but its place on the crest of this arch would be nearly 500′ above water level. It then descends to the railroad (as shown on page plate XXVII, G7, 342).

† If the *Corniferous* formation can decline to nothing, so can the *Lower Marcellus.* The fossils will of course come in and go out with the material favorable for their existence; their presence or absence can not compel us to violate the ordinary rules of sedimentary geology; they do not indicate the age, but only the character of the deposits of a known age. The hundred

The Georgetown exposures, 12 miles lower down the river, show a wonderful contrast to those at Selinsgrove. The *Marcellus dark shale* appears to be only 25′ thick here;* but the *Corniferous limestone* is 75′; and the underlying *Caudagalli gray shale* only 50′. The *Corniferous* is here a mass of very hard, gray, limy shale, containing a few layers of very impure gray limestone.

VIIIa on the N. Br. Susquehanna. Limits of the Selinsgrove lower limestone.

If we ascend the Susquehanna from Selinsgrove 25 miles to Bloomsburg we find exposed along Fishing creek, on the north side of the Montour arch, *Marcellus* black fissile, non-fossiliferous slates 225′; *Corniferous* (?) very hard, dark grey beds containing some *lime* and many *iron concretions* 25′; dark fissile slates (some of them grey) 100′; (unknown rocks concealed for 75′); *Caudagalli* looking slates 25′; no Oriskany sandstone, but black and then ash colored shales 100′; down to the No. VI limestone beds (G7, 219).

Here then we seem to have a *northern limit* to that charge of lime in the seawater which produced the *Selinsgrove lower limestone* formation.

Had it also a *southern limit?* We have already noticed an approach to one at the Lehigh water gap. We seem to have one at the Susquehanna water gap near Harrisburg; no trace of any *Corniferous* (*Selinsgrove*) *limestone* formation has been detected either on the Dauphin county bank, or on the Perry county bank of the river where it cuts through the *Hamilton* into the *Salina* and *Clinton* formations. But it has been repeated several times that the southern side of the Dauphin county coal basin is turned

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miles of interval underground between the Delaware river outcrop in the east and the Susquehanna outcrops to the west of it afford ample space for any amount of variation in the special features and total thickness of the formation.

*In fact the *Marcellus* as a *black* deposit cannot be found at all. On the other hand the overlying sandstones of the *Hamilton* are greatly increased. (See next chapter.)

up to and beyond the vertical, for a distance of some miles east and west of the Susquehanna water gap (see section on page 277); that about 1000 feet of VIII, VII and VI are absent from the series; reappearing in their proper places near Sterrett's notch at the west end of Rye township, Perry county; and that their absence may be explained on two very different theories: either that they were never deposited; or that the great upturn has produced a virtual fault along the strike, and shoved the *Hamilton* rocks up, over the crushed or broken edges of the *Marcellus*, *Corniferous*, *Caudagalli*, *Oriskany* and *Lower Helderberg*, so as to rest against the *Salina*. If the latter view be correct, the question of a southern limit to the *Corniferous* (and the rest) cannot be answered; for the evidence remains underground and not to be cross-examined. If Prof. Claypole's theory be accepted, this conclusion that dry land existed in this area of the state may possibly be correct; but not necessarily; for there is an alternative, namely, that the deposition of the missing formations was located by a current of a definite width in miles (like the gulf stream), and that the southern edge of the current marked the southern limit of the formation. But even so, if the great synclinals and anticlinals were smoothed out into their original horizontal position, we should still be obliged to locate the southern limit of the deposit much further south somewhere between Columbia and the Maryland line.*

*The theory of dry land existing in this small area or extending from it southward into continental lands; or rather the theory of dry land existing originally to the south of this in the places to which the smoothed-out folds would remove it, and thence southward, encounters two objections:—1, that the general increase in thickness and coarseness of the Palæozonic formations southward (as far as we can study them, that is, as far as the Blue mountain line of out-crop) goes to tell not of dry land in that direction but of deep water; and, 2, that Professor Claypole's observation (F2, p. 309) that "careful examination shows that the lower beds of the limestone (No. VI) at Sterrit's Gap are the first lost, and the highest, the flint beds, persist farthest (that is, eastward, towards the Susquehanna gap) beyond which the Lower Hamilton shale alone exists," is contrary to what we have a right to expect of the theory of dry land producing by gradual emergence; for wherever the sea bottom gradually emerges, the feather-edges of

VIIIa. Corniferous in Perry county.

We have seen that the *Corniferous* formation on the Delaware, Hudson and Mohawk is characterized by nodules of flint (which give it its name) and by a number of genera and species of animal forms living at the time of its deposit, the most of which had not lived before, and did not continue to live afterwards, being succeeded by genera and species supposed to be peculiar to the age of the overlying black *Marcellus shale.* The organic (sponge) origin of the flints is hardly to be doubted ; and the natural habits of the Corniferous shell-fish must have been in harmony with the quality of the sea-water, holding in abundance lime and silica, in which they passed their lives. Whence came this copious infusion of lime water, why it commenced, and why it ceased, are questions which we cannot answer ; but the supposed narrow belt-like shape of the deposit, extending east and west from the Delaware to the Susquehanna, suggests some special oceanic current, which may have had its starting point at the mouth of some great river in the far east. The varying character of the deposits made by such a current along its course would explain differences of character in the deposits under consideration from east westward.

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successive formations are left in the rear of each other, the lower projecting beyond the upper landward.

Our ignorance of the real state of the case in southern Perry county is still very great; but on the whole it seems to me that the balance of probabilities favor the theory of a slide-fault along the Blue mountain ; on the other hand the removal of the original locality to many miles southward of its present position increases the probability of a southern limit. Supposing this southern limit to be approximately a straight line, it must be drawn on our present maps from the southwest corner of Rye township, Perry county, to the Lehigh Water gap. But, restoring the original horizontality of the Palæozoic formations, the line should make a great curve, convex toward the south, from say Carlisle to Allentown. *If all* the folds which exists between the Allegheny mountain and the Blue mountains were flattened out it is evident that the whole belt of Corniferous deposits would be transferred to a southern latitude. But it must be kept in mind that such a belt has not been completely demonstrated ; nor can be ; because the formation lies out of sight underground beneath the whole anthracite region between the Lehigh and Susquehanna rivers ; and we will see that in Perry county it is a most irregular deposit ; its expanse hardly corresponding to the meaning of the term "belt."

It has been shown that the limy deposits which succeeded the Oriskany sands and preceded the Marcellus black slates are full of flints and Corniferous shells along the Delaware; but are almost destitute of flint, and lose all their *Corniferous* shells, before reaching the Susquehanna; so that Prof. White abandons the term *Corniferous* of his Delaware river report, and substitutes the term *Selinsgrove Lower limestone* in his Susquehanna report.

We are now to see that, in the county west of the Susquehanna, this change in the deposits becomes still more remarkable. Flint entirely disappears from the formation; massive limestone beds become comparatively rare; and what thin limestone beds remain in the deposit are separated from each other by black shale partings so much like the black shales of the overlying Marcellus formation that they cannot be distinguished from them. What will arrest the attention of the palæontologist is the fact that not a single *Corniferous* fossil species has been found by Prof. Claypole in Perry county; while, on the other hand, the limestone formation over the Oriskany is crowded with species which are considered characteristic of the *Marcellus*. Consequently, reasoning as a palæontologist he rejects the term *Corniferous* and substitutes that of *Marcellus limestone*, which he includes in the Marcellus black shale formation. He concludes that the *Corniferous formation* was never deposited in Perry county, and uses this conclusion in his argument for the existence at that time of dry land, not only around the Susquehanna Water Gap, but over the whole region of the Juniata. And in doing this with the *Corniferous* he does the same with the underlying *Caudagalli*, saying that the *Hamilton* in many places lies directly upon the *Oriskany*.

Were it not for the hazardous nature of conclusions made under the influence of palæontology I should accept more readily this nomenclature. But as the fact remains unchanged by the absence or presence of flints, the quantity or paucity of limestone beds, the absence of characteristic *Corniferous* fossils and the presence of characteristic *Marcellus* fossils,—as the great stratigraphical fact remains that the deposit of the *Oriskany* sandstone was followed by deposits of sandy shale, then by deposits of lime shale and limestone, then by a great deposit of black shale, and finally by a great deposit of sandrock,—it makes no difference by what names we designate these successive formations in view of the fossils which they contain; they certainly preserve the regular succession of *Oriskany*, *Caudagalli*, *Marcellus* and *Hamilton;* and therefore I can see no reason for not retaining the old names, while describing the changed characters of the formations which would naturally carry them. I shall therefore continue the description of the *Corniferous formation* in the lower Juniata district region, with the understanding that the formation is the same, but that its character differs from anything we see in eastern Pennsylvania.

Paint ore in Perry county.

In describing the Oriskany sandstone the fact was mentioned that in a few places in Perry county a bed of iron ore overlies it, which has been dug for the manufacture of paint in one or two places; corresponding to the paint ore of Rocky ridge at the Lehigh Water gap.*

At Montebello a peculiar hard sandstone bed, one foot thick, lies upon the Oriskany. It is overturned to 85° S. E. In the Tuscarora valley of Juniata county at Peru, and for some distance east and west of that village, the Oriskany is overlaid by a peculiar sandstone, 3′ thick, fragments of which cover the ground. It differs entirely from Oriskany sandstone, and contains no fossils; but it holds an abundance of pebbles from the size of a chestnut down to mere grains of sand. It is heavily impregnated with iron; and its fragments look like rich ore; but on being

*This *Oriskany ore* must not be confused, as it has often been with the *Marcellus ore*. Where the interval *Caudagalli-Corniferous* deposits become so thin as to let the *Marcellus black slate* almost down upon the back of the *Oriskany* the *Oriskany ore* and the *Marcellus ore* outcrops run close together; but the characters of the two ores differ widely; the former being liver colored and siliceous; the latter a soft brown hematite. This will appear more clearly in the Lewistown valley region of Mifflin and Huntingdon counties.

broken they are found to have a solid core of sandstone, covered with a crust of iron.

The limeshales and limestones.

A lime shale formation overspreads the Oriskany pretty uniformly throughout the county, and is at one place 50′ thick. It consists of thin beds of gray clay limestone and gray shales. It seldom contains any fossils, and those which do occur are so indistinct and difficult of extraction as to be nearly worthless for palæontological study. In the Madison township exposures fossils are numerous.* These limeshales graduate upward into a limestone formation, which becomes in some places 50′ or even 75′ thick, solid good limestone strata, separated from each other by part-

* In Spring township, the *Corniferous* strata are sufficiently well exposed at Gibson's Mill; and again about a mile north of it, along Sherman's creek near Falling Springs the harder limestone beds are displayed, 50′ thick, containing a few fragments of trilobites (? *Dalmanites*). At the other exposures the same (? *Dalmanites*) and *Atrypa renticularis* may be found. Falling Spring creek enters Sherman's creek over the *vertically upturned* edges of these limestone beds.—Another good section shows on the Perry furnace road to Adam's Glen S. H. where the fault cuts the Oriskany ridge; thickness of limestone and shale seen 40′; fossils the same.—Ledges of the limestone appear in the road at Rice's; exposure 75′ thick; limits concealed. (F2, 339).—In Tyrone township, the only exposure is in the high knoll opposite Oak Grove furnace. where black shale and much iron ore have been quarried (F2, 375).—In Centre township, where the iron ore has been extensively quarried, between long synclinal strips and tongues of Oriskany, the overlying limestone formation is seldom seen. But it displays itself on Barnett's farm near New Bloomfield, where lime burning has proved a failure, as the lime would not slake.—In Miller township, loose blocks of (*Corniferous*) limestone are abundant at the north end of Pine Grove narrows, thrown out of trial pits for ore. *Marcellus shale* has been thrown out some of these pits.—In Watts at Half Falls mountain gap, the limestone is mentioned by Prof. Rogers in his Geol. Penn. 1858, Vol. 1, p. 138 (from Dr. Henderson's report) as visible in the bed of the Juniata, lying under 180′ of black *Marcellus shale*.—In Buffalo township the limestone is not reported.—In Madison, the limestone beds are given in the text.—In Tuscarora township no limestone outcrop has been noticed.—In Greenwood also, along the north slope of Wild Cat ridge, and south slope of Turkey ridge, the outcrops are concealed by the *débris* from the Hamilton sandstone crests; and in Liverpool township the head of Pfoutz valley is covered with surface drift. We should therefore know nothing of these rocks along the range of the Tuscarora anticlinal were it not for the cut of the Susquehanna through them at Georgetown in Northumberland county, as described in the last chapter and for the exposure at Half Falls mountain mentioned in the text.

ings of dark shale, resembling Marcellus shale. The only continuous section was got in Madison township, west of Centre mills dipping 40° to the north, as follows:

Centre Mills Section, F2, p. 262) 66 feet.

Limestone of Tudor and Rice's quarries.

Dark shale and limestone interbedded (Tudor's quarry),	12′	
Dark shale,	4′	
Lime shale, greenish,	15′	
Shale, smooth, greenish,	6′	
Shale, sandy, green,		6″
Shale, soft, green, weathering red,		6″
Flint bed No. 3, oolitic, square fracture,*		2″
Shale, rubbly, green, weathering red,	3′	
Flint bed No. 2, oolitic hard,*		4″
Shale, rubbly, green, weathering red,	6′	
Flint bed No. 1 oolitic, hard,*		4′
Blue clay,	1′	
Iron ore, slaty, liver colored,	2′	
Oriskany sandstone, soft,	15′	

Atrypa recticularis, *Leiorhynchus limitaris*, *Strophomena rugosa*, *Ambocœlia umbonata*, *Discina seneca*, *Beyrichia unguta* (new species), *Coleolus* (*Coleoprion*) *tenuicinctus*, *Styliola fissurella*, *Phaeops rana*, make up Prof. Claypole's list of fossils in these beds.

Tudor's quarry, near Centre mills, show very well the limestone and dark shale alternations. Here the limestone beds are used for both building and lime-burning. The order from above downwards (placing the thickness of the dark shale partings in parentheses) is as follows:—limestone 2″ (dark shale 1″) 2″ (2″) 6″ (3″) 6″ (1″) 4″ (1″) 8″ (3″) 6″ (4″) 8″ (4″) 12″ (6″) 4″ (2″) 6″ (3″) 6″ (3″) 8″ (1″) 12″ (1″) limestone at bottom. Total 10′ 7.″

Here we have 15 beds of hard solid limestone alternating with 14 beds of dark shale resembling some of the beds in

* It has been said that flints entirely disappear from the formations over the Oriskany in the Juniata river country; but this is not strictly correct, as the Centre mills section shows; for the paint iron ore bed cuts off the three flints beds at the bottom of the section from the *Oriskany;* and these flint beds serve to show that the Corniferous conditions of the sea water were as real although they did not last so long in the water area west of the Susquehanna, as in the Delaware river area, or the area of the north branch of the Susquehanna.

the overlying *Marcellus* formation ; black when wet, but drying to a peculiar reddish color. Characteristic *Marcellus* fossils may be got from several of the lower beds of black shale.

It is evident that the conditions of the Appalachian sea in the Corniferons age in this part of the water basin were giving place to the conditions which became afterwards prevalent over most of the great sea bottom ; and the early appearance of *Marcellus* shells (not in the limestone beds but in the dark shale partings between them) was the natural consequence. They are no argument against the *Corniferous age of the deposit*, which as a whole is evidently a limestone formation.

Rice's small quarry on an adjoining farm shows similar alternations in the following order, (2″) 14″ (4″) 4″ (5″) 6″ (4″) 18″ = 4′ 7″ (see vertical sections F2, p. 250, pl. 26).

Half Falls Mountain section.

Where the Juniata breaks through the *Hamilton sandstone* ranges of Half Falls mountain between Watts and Miller townships, the following series of formations is brought up by the great Perry county anticlinal and exhibited in the river bed*.

Marcellus black fissile slate, with its usual small fossil shells, ...	about 180′
Iron ore bed. †	variable.
Limestone ; no flints ; light color ; partings of greenish shale ; *Atrypa limitaris*, etc.,†	20′
Gray and buff limeshales, with several minute fossil shells,†	25′
Oriskany sandstone, No. VII.	

The limestone was found by Henderson to preserve its aspect and thickness with little change every where in Perry county except in Rye township along the Blue mountain to the Susquehanna water gap ; where the underlying shales and *Oriskany* and the overlying *Marcellus* are also

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* Dr. A. A. Henderson's survey of 1849, published in Prof. Rogers' Geol. Penn. 1858, Vol. 1, p. 138, 356.

† Prof. Claypole has simply followed Henderson and Rogers in calling the whole group *Marcellus* (*Cadont older blackslate*) down to the *Oriskany*.

wanting. At Half Falls gap the limestone is tolerably pure (Geol. Pa. 1858, I, p. 358).

VIII a, Corniferous on the middle Juniata.

Over the *Peru sandstone* in the Tuscarora valley, for several miles east and west of Peru, lies a small series of hard thin bedded limestone layers, breaking up into long narrow blocks; but beyond this district, hard yellow square-fractured shales prevail.*

In a general way it may be said that the *Oriskany* is covered throughout Juniata, Snyder, Mifflin and Huntingdon counties by a hydraulic-lime shale and limestone formation which we may call *Corniferous shale.*† In Snyder county there are but 30′ or 40′ of this shale; in Tuscarora valley in Juniata county, more than 100′; at Lewistown in Mifflin county, 133′; at McVeytown, 110′; at Mount Union, say 70′; at Orbisonia in Huntingdon county it is apparently represented only by a bed of clay resting on the *Oriskany*. But at the east end of the range, in Snyder county, this shale formation wears the aspect of a series of fine grained yellowish sandstone beds, fossiliferous and calcareous, and only appearing shaly at the outcrop by the weathering out of its lime.

The *Corniferous limestone proper* (called *Upper Helderberg limestone* in Report F) has its horizon everywhere defined by contact with the base of the Marcellus black shale. —In Snyder county it is a mass of greenish limestone beds, 40′ thick. At Peru in Juniata county the top layer is a good pure lime sandstone. At Lewistown may be seen 40′ of dark green limestone, crumbling at the surface into light green shales. At McVeytown 40′ of black limestone is divided up into beds 12″ to 6″ thick, separated by black clay-slate, a condition of the formation already described by the Centre-Mills section in Perry county; some of the limestone beds being hard, gray and sub-crystalline. In southern

*It seems to be quite correct to say that the *Caudagalli-grit* formation cannot be detected in this region of the middle Juniata.

† This is the name given to it in Report F, on the Fossil iron ore beds of middle Pennsylvania, 1878.

Huntingdon, from Orbisonia to Fort Littleton, the outcrop decomposes into green shales.—Everywhere the layers of this formation seem to be more or less *hydraulic;* when burned, the lime hardens instead of slacking, and is therefore generally rejected by the farmers.*

In Bedford and Fulton.

Prof. Stevenson agrees with Rogers and Claypole in ignoring the Corniferous, and in bringing the Marcellus down upon the Oriskany. And yet, under the characteristic dark Marcellus shale "increasing in blackness towards the base, and many of the layers wrinkled like gneiss, a characteristic of the Marcellus over a great area," 308′ thick, he found in the only satisfactory measurable exposure (at Saxton) the limestone and lime shale series which usually comes at the Upper Helderberg horizon. It consists of limestone layers (12 in number) only 2″ to 6″, except one 12″ bed, and parting shales from 2 inches to 12 feet thick; the whole exposure 68½ feet thick; under which a concealed interval of 84 feet down to the Oriskany sandstone. In this interval appear to be fewer limestone layers and more shale partings, and of very dark color, like the Marcellus. "Exposures elsewhere show that the black shales with limestone extend down to the Oriskany." Iron ore occurs at the bottom along Warrior ridge; corresponding to the Paint bed of Perry and Carbon counties. The only fossil seen by Stevenson was a broad winged lamellibranch shell, a *Pterinea* of Hamilton affinities, but which could not be extracted from the rock to determine its exact species (Stevenson's Report T2, 1882, p. 83).

The Corniferous in Western Pennsylvania.

Whether the Upper Helderberg limestone formation underlies western Pennsylvania in one broad sheet or in patches with vacant spaces between or where such patches exist will never be known, for its depth beneath the Coal

* It is said that the hydraulic cement used in the construction of the Schuylkill canal was made from quarries of this limestone near Perryville in Juniata county.

Measures is too great to be reached by oil borings. This subject is treated by Mr. J. F. Carll in his seventh report on the Oil and Gas Fields, Report I5, 1890, chap. 4, pages 71 to 80.

In Greene county in the southwest corner of the State the Corniferous is calculated to lie at a depth of 6875 feet beneath the highest rock left uneroded on the highest hilltops. In a north direction the formation rises so slowly that it has not been reached by the Westinghouse test well at Pittsburgh 4618′ deep. But it is supposed to be struck at the bottom of the Conway well on the Allegheny river, nine miles below Franklin, 3880′ deep. * It was undoubtedly struck by the Wheatland well near Middlesex in Mercer county, 3484′ deep. † Finally, it was struck by the Presque Isle well at Erie (4460′ deep), at a depth beneath the surface mouth of the well of only 1325′, and extended down to 1600′. ‡

The general slope of the formation from Lake Erie into W. Virginia can be best seen by comparing the *ocean level data* in these wells. The Erie well strikes the top of the Corniferous at 725′ B. T.; the Wheatland well at 2517′ B. T.; the Conway well at 2900′ B. T., and at Pittsburgh it lies an unknown depth beneath the Westinghouse well bottom, 3733′ B. T.

Many wells in Ohio have gone down to the Corniferous, striking it at various depths, from 387′ above tide to 2200′ below tide. Mr. Carll has skilfully constructed a most interesting underground contour line map of the formation,

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*See the record in I5, p. 185. The well stopped in "brown limestone," 3275 beneath the base of the Third Venango Oil Sand.

† See record in I5, p. 230. This well passed from the bottom of Marcellus black slate at 3377′ into "Limestone, black to gray, cherty (Corniferous)," and went down in limestone 107 feet, leaving off still in limestone.

‡ See record in I5, p. 187. The limestone beds passed through were: light colored, 75′; gray, 165; light, coarse, 35; brown, porous with salt water, 40; ferruginous, 10; gray, 15′; with shale, 35′; beneath which came marl, 40; gypsum, 10′, etc. The salt water indicates the Salina formation, consequently the Oriskany sandstone seems by the record to be absent, and the Helderberg limestones proper to be only 275′ thick, of which the upper part must represent the Upper and the lower part the Lower Helderberg rocks of the east. But well records as usually reported by the well sinkers are poor materials for geologists to draw conclusions from.

published in his Report I5, plate 3, a copy of which on a very reduced scale I give on plate CL. B., page 1166, of this summary. *

The Corniferous as a Source of Petroleum.

Wherever the Oriskany sands and sandshales are absent the Upper and Lower Helderberg limestones and limeshales come together and make practically one formation. This happens in the region west of New York and Pennsylvania. In western New York the Niagara limestone holds animal oil usually in cast cavities of cupcorals. All the Waterlime quarries smell of petroleum, and many of the limestone beds are fetid or stink of oil (page 890 above). In the London district of Canada, east of the Detroit river, a great yield of fetid animal petroleum was once got from scores of wells bored through a heavy covering of glacial gravel, sand and clay, into the Corniferous limestone in which the oil was supposed to originate by decomposition of fossil corals, although the real source may lie deeper in the underlying Waterlime or Niagara formations.† It was in search of this "Canada oil" that the Conway and Wheatland wells were sunk, and it is possible that were

*I have cut off his map on the south at the latitude of Pittsburgh, although some of his Ohio wells lie south of that parallel. The contours could not be carried southeast towards Pittsburgh on account of the Brady's Bend and other anticlinals which cross the Allegheny and Monongahela rivers. But any one can extend them to the Hudson by using the New York well records of Prosser and Ashburner. The formation rises along the shore of Lake Erie, and at Fredonia is only 315′ B. T. Still rising it comes to the surface at Black Rock, the foot of the Lake, at 625′ A. T., and its outcrop runs thence east the length of the State, as already described. In McKean county it must underlie the deepest of the Bradford Oil Wells at least a thousand feet, since the Bradford sands lie a thousand feet beneath the Warren sands, and these a thousand feet beneath the Venango group, beneath which the Corniferous lies in the Conway well about 3270′, and in the Wheatland well 2635′ (Carll, page 73). At Ithaca a well struck the top of the limestone at 1298′ B. T. (Letter of H. S. Williams, Dec. 24, 1887).

† In Canada the corals often prevail in distinct bands, some of which will be saturated with the oil, while others will not. Petroleum springs rise from this group at Tilsonburg and other places. At Kincardine and elsewhere slaty beds contain 10 to 15 per cent of solid petroleum, mineral pitch, or bitumen soluble in benzole. No good well has been got by boring into the rocks. The source of the oil is in the Waterlime or lower shales (S. A. Miller, Am. Geol. and Pal., p. 60).

the Conway well put down several hundred feet deeper fetid animal petroleum would be got. But in no part of Pennsylvania has any oil been got from the Upper or Lower Helderberg, nor is there a sign of oil in them anywhere along their numerous and extended outcrops.

The fossils of the Corniferous. Plates CXXXVII to CLIX.

The range of the coral reefs of the Upper Helderberg through the United States is as great as that of the Niagara. "It is grandly exhibited at the Falls of the Ohio near Louisville where corals are crowded together in great numbers, some standing where they grew, others lying in fragments as they were broken and heaped up by the waves, branching forms of large and small size mingled with massive kinds of hemispherical and other shapes. Some of the cup corals (Cyathophylloids) are six or eight inches across at top, indicating a coral animal seven or eight inches in diameter. Hemispherical compound corals occur five or six feet in diameter. The various coral polyps of the era had beyond doubt bright and varied coloring like those of our own tropics; and the reefs were therefore an almost interminable flower garden." (Dana's Manual, p. 255.)

The sea weeds are of the Spirophyton type. The hornstone is shown by Dr. White to be full of microscopic plants (1–500 to 1–5000th of an inch) mixed with the needle-like skeletons of sponges, and the minute teeth of shell fish. (Dana gives pictures of them in Fig. 484 A. p. 257 of his Manual.)

The land plants of the day were Lycopods (ground pines), *Psilophyton* like those of the preceding Oriskany period, with flowering stems but no leaves; also conifers, the earliest known genus *Prototaxites;* also ferns *Caulopteris antiqua*, Newb.

Of animals we have the sponge spicules of the flint stones; cup corals, *Cyathophylla;* honey-comb corals, *Favosites;* bud crinoids, *Blastidea* (like the armless and stemless *Nucleocrimus verneullii*) predicting the innumerable *Pentremites* of the Coal Measures; brachiopod shells, *Productus*, which became so abundant in the Carboniferous age; gasteropods *Platyceras*, and their teeth; lamellibranch shells, Lucina, Conocardium, Solenomya, Orthonema; Pteropods, *Tentaculites;* cephalopods, *Cyrtoceras;* articulates, the trilobites *Dalmanites*, *Proetus*, *Phacops;* fishes, sharks, *Machæracanthus*, *Spinax*, *Cestraceon;* ganoids, *Holoptychius*, *Onychodus*, *Cephalaspis*, *Placodus*, *Rhynchodus*. (See figures in Dana's Manual, pp. 263, 264.) *

Phacops rana and *Atrypa reticularis?* were found by Claypole in Marcellus (U. Helderberg ?) limestone at Smith's quarry, Perry county (O3, p. 137).—*Strophodonta perplana* and *demissa*, and *Leiorhynchus multicostatum*, at Pine Grove (p. 148).—*Ambocœlia umbonata* and a *Bellerophon*, at Falling Spring (p. 158).—*P. rana*, a *Proetus*, a *Fenestella*, a mile N. E. of Bridgeport (p. 161).—*Tentaculites scalariformis* from acknowledged Corniferous strata at Stroudsburg, Monroe county (p. 164). The flint nodules often enclose shells and corals. A list of the fossils by Prof. White is given on page 1692 above and need not be here repeated. His list of the Selinsgrove limestone fossils is given on page 1179 above. For the Perry county fossils see page 1182 above. For the *Pterinea* in Bedford county see page 1189 above.

Prof. White says that the Selinsgrove *upper limestone* is the base of the Hamilton and the *lower limestone* the base of the Marcellus; that the latter occupies the horizon of the Corniferous "that its one Corniferous fossil *Leptocœlia acutiplicata* is more than offset by the Hamilton form *Ambocœlia umbonata*" (G7, p. 80.) I do not comprehend how one fossil species can "*more than* offset" another in evidence of the age of the strata which embed it.

* Its fish remains, teeth, scales or plates, are so abundant as to make up solid layers 3 or 4 inches thick. The *Macropetalichthys sullivánti* had a head covered with bony plates enclosed in a skin studded with tubercles 15 inches long.—The characteristic corals were *Cyathophyllom rugosum*, *Favosites goldfussi*, *Syringopora maclurii*, *Phillipsastræa verneuilli*, *Nucleocrinus verneulli;* shells, *Spirifera acuminata*, *S. gregaria*, *Pentamerus Knightii*, *P. aratus*, *Stricklandinia elongata*, *Paracyclas occidentalis*, *Conocardium subtrigonale*, *Platyceras dumosum*, *Tentaculites scalariformis:* trilobites, *Dalmanites selenurus*. (S. A. Miller, p. 60.)

CHAPTER LXXXIV.

No. VIII b. Marcellus Black Shale. *

We enter now upon an age or series of ages of mud and sand, leaving the limestone world beneath our feet. The sea deepens to receive the black deposits of the *Marcellus*,†

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*The *Marcellus (Cadent lower) black slate*, with layers of impure limestone at Selinsgrove, is 655′ thick; at Lewistown several hundred feet; in White Deer Valley (fissile black slate, with large lenticular cakes of blue limestone and secretions in its lower half, becoming more continuous southwest, its fossils few), from 600′ to 800′; near Frankstown (with cement layers near its base) more than 300′; on the Potomac at Cumberland more than 400′; on the Potomac near Sideling Hill (ash-colored and black slate, passing up into black fissile slate and impure clay limestone), 590′. It continues in force into the interior of Virginia, and then steadily diminishes to disappear in Eastern Tennessee. The black slate of the Western States is supposed to be not *Marcellus* but *Genesee* (Rogers, 1858, Vol. I, 138).

† If one wished to publish a sensational generalization he might say that *all limestone formations are followed and overlaid by black slate formations*, as witness the Lower Silurian black Utica on the Trenton; the Devonian black Marcellus on the Corniferous; the black Genesee on the Tully; the sub-carboniferous black slate and coal of Lycoming county on Mauch Chunk limestone, and the numerous coal beds and roof slates on the numerous isolated carboniferous limestone beds. But a thorough investigation of the generalization would strip it of any supposed significance, and leave it as a mere fanciful hypothesis, a vague suggestion of one important and as yet unexplained structural relationship between deposits of lime, mud and black clay mud, superposed in contact in many geological ages. It may well be that the old black mud deposits were not black when deposited, but have become black in the lapse of time. If so, some explanation of the production of their black color must be sought. The knowledge which we have recently obtained of rock-oil and rock-gas may furnish the explanation. It may be that the abundance ot animal life in underlying limestone formations may account for it in some cases. That the decomposition of soft animal and vegetable tissues has originated the petroleum is now a well demonstrated fact. Gases generated in the process have certainly pervaded overlying rocks. The microscope however may some day show that what we call *non-fossiliferous* black-shales are more fossiliferous in their way than limestones full of large shells and corals. Certainly the black roof-shales of coal beds were not blackened from the limestones which underlie the white fire-clay floor of coal beds, but either by exhalations from the coal bed, or more probably by their own *original* large percentage of vegetable matter like the humus in a soil.

and then the *Hamilton* sand; then again the soft black mud of the *Genesee;* and again the fine sand of the *Portage;* then the vast inpour of mingled mud and sand of the *Chemung;* and finally an interminable series of gray and red sands, muds, and occasionally gravel, the *Catskill* formation, which finishes the *Devonian system*, † and prepares an oceanic bottom for the *Carboniferous system.* Ten thousand feet of these Devonian sediments remain in the deeper folds of middle Pennsylvania, and their upterned edges may be studied along innumerable zigzag outcrops.

The outcrop of the *Marcellus black shale*, only 50′ feet thick in western New York, closely follows that of the Corniferous and Oriskany from Buffalo eastward, past the mouths of the little lakes and along the flat top of the Helderberg; southward along the foot of the Catskill mountains; southwestward along the Valley of the Esopus and Fishkill, by the line of the Delaware and Hudson canal; down the Delaware river to Walpack Bend, and thence by Stroudsburg across the Lehigh, Schuylkill and Susquehanna (above Harrisburg) into middle Pennsylvania; and finally into the Southern States. Its thickness is seldom greater than 300 feet; but along the interior outcrops of the

† This Devonian system, says Hall, viewed as a whole presents a general similarity in its products of their causes, with alternations of dissimilar materials and corresponding changes in its groups of animal life forms, each of its great sub-divisions being strongly marked by its organic types peculiar to itself, while some species which began to live in its earlier deposits continued to live to the latest. The lines of demarkation between the great sub-divisions are locally well defined, but in general such lines are not sharp, but sub-division slides into sub-division by a series of passage-beds partaking of the nature of both, in which the characteristic rocks and fossils of each are repeated again and again until those of the earlier sub-division cease and those of the following sub-division prevail. In western New York the sub-divisions are clearly distinguishable; in eastern New York they grow less distinct, and in southern New York and Pennsylvania it is in many places difficult or impossible to assign their limits. Along the New York outcrop all the members of the system grow thinner westward, their fossils less abundant, until at last the mass is nearly or quite non-fossiliferous. In the east the rock character is similar throughout the greater part of the mass of the system; westward the shales (somewhat calcareous) are confined to the lower part, and the sand or sand and shale alternations to the upper, and this holds good nearly to the Mississippi river (Hall 1843, p. 176).

upper Juniata and West Branch of Susquehanna it exceeds 800′.*

In Western New York the *Marcellus* is in two divisions:—*the lower* very black, slaty, bituminous,† full of iron pyrites, in portions calcareous, always holding courses of balls (concretions, *septaria*) often of large size;‡—then a thin bed of limestone;§—then *the upper* division, more fissile, black, passing upward into dark slate colored or olive shale, *passing insensibly upward* and *carrying its fossil species* into the overlying *Hamilton* formation.

Its outcrop occupies a continuous vale or depression to the south of and from two to four miles distant from the

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* "Over the whole area known to be occupied by the *Corniferous limestone* there is an abrupt change from that rock to a black fissile argillaceous slate; while fossils, which have been abundant in the limestone, either cease entirely or are succeeded by others of a totally different character" (Hall, 1843, 176). This was written nearly fifty years ago, and requires a little modification, as will be seen in describing the Pennsylvania area, in some parts of which the black mud deposits lie directly upon the Oriskany sandstone and interbedded with the Corniferous limestone. If it be convenient to call the black mud *Marcellus*, it is equally convenient to call the limestone *Corniferous;* but a convenient naming must not impose upon us an untrue meaning. The deposit of black clay mud evidently began sooner south and west than it did north and east, and was far more abundant, being scarcely if at all interrupted by the lime sediments. What few shells could live in it lived in it from the beginning—that is, even before the lime sediments encouraged the temporary immigration of *Corniferous* species. We find therefore, Marcellus shells in the *Corniferous* lime group of middle Pennsylvania, with an almost total absence of cornstone. Hence also sharp limits can be assigned to the Corniferous downward and upward in one district but not in another along the New York outcrop, but not in middle Pennsylvania. This renders the *measurement of the Marcellus formation* almost everywhere a delicate and doubtful matter.

† So bituminous in places that it flames when thrown upon a fire of hot coals. It has been ignorantly explored for coal the whole length of New York; and hundreds of farmers have done the same along its many lines of outcrop in Pennsylvania. On the lower Juniata it actually contains exceedingly thin layers of a kind of coal.

‡This division of the *Marcellus* cannot be distinguished from the *Utica slate of No. III*, so many ages older; nor from the *Genesee slate* (*No. VIIIc*) two ages later. It indicates a wide quiet ocean, with broad gentle water movement in which the most delicate and fragile animals lived in great numbers, and their remains were preserved in the greatest perfection; so packed and crowded together in places that they cannot be easily separated (Hall, 1843, 177).

§ This may represent the Pennsylvania in *Selinsgrove upper* limestone (50′ to 75′ thick) to be described further on (G7, 78, 346, 360, 371).

ridge-like outcrop of the Corniferous (the top of the Helderberg in eastern New York) on account of the exceeding gentle southward dip and the softness of the mass.*

The fine leaves into which some of the Marcellus black slate splits are made by millions of specimens of a thin smooth shell *Pteronites* (*Avicula*) *muricatus*, exceedingly thin and brittle, the broken pieces of which appear upon the surfaces of the laminæ when they are split apart.† Mixed with these there are also flattened pieces of a straight shell *Orthoceras subulatum*

The limestone bed, one foot thick, which separates the upper and lower divisions of the Marcellus contains at Vienna a large number of *Orthoceras subulatum* (the only species present) and a whorled shell (*Euomphalus*) very fragile, and lined inside with calc spar crystals; also a fragment of the trilobite *Dipleura* (now *Homalonotus*) *dekayi*, which is usually found in much higher rocks. On Flint creek the limestone bed is compact and full of fragments of shells; roofed and floored with laminated black shales, their surfaces covered with fossils; the 20′ of it under the limestone beds contains large balls of siliceous limestone,‡ and others of clay limestone. At LeRoy § these concretions again crowd the compact black slate *beneath* the limestone bed; while the fissile black slate *above* the limestone abounds in fossils.

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* Long weathering turns the black rock to a brown or iron rusty color; but sometimes it remains permanently black. The decomposition of the *iron pyrites* which pervades the mass has facilitated its erosion into valleys. The beds of the smaller lakes of New York are excavated crosswise (from north to south) in it; and in the southern region, where the formation is vastly thicker but equally fit for erosion, the broad and deep channels of the Delaware, Susquehanna and Juniata rivers, and many of their largest tributary creeks have been ploughed out along its steeply dipping outcrops, in straight stretches of many miles. Some of these ancient channels were filled during the ice-age with Northern Drift and abandoned by the rivers, which made newer side channels for themselves; but the old channels can still be traced along the deserted valleys, bounded by hills of Corniferous limestone on one side, and hills of Hamilton sandstone on the other.

† See the natural exposures south of Waterloo in Seneca county.

‡ In these septaria often occurs *sulphate of baryta;* and also calcspar.

§ In the ravine of Conesus outlet, a little west of Avon, and the bed and banks of Allen's creek near LeRoy, are the best places for a student.

Marcellus fossils in Western New York.

These are nearly all small delicate and fragile, and yet have been beautifully preserved, being often as perfect as when living.* They pervade the formation, especially its upper half, in incalculable multitudes ; and when we consider the infinite quantity of soft cellular tissue which was produced by so many millions of little lives, generation after generation, spawned with a prolific energy and rapidity perhaps equivalent to that of fish roe, and in the case of the trilobites to that of the insect world,—tissues fed upon in part by creatures of larger dimensions whose remains are scarce in comparison, but whose numbers must have been immense,—the larger part of which however must have been decomposed into petroleum and gas,—no other explanation of the blackness of the formation is necessary.

Ambocoelia umbonata (*Orthis nucleus*), a little hemispherical shell with a hinge line only about three-sixteenths of an inch long, is so abundant that a thin layer of rock will sometimes be found wholly composed of individuals, the mud cement being hardly sufficient to stick them together.—*Leiorhynchus* (*Atrypa*) *limitare* also forms sheets in the upper shale, considerable thicknesses of rock being completely charged with them ; often in company with multitudes of *Discina* (*Orbicula*) *minuta* which cover the shaly laminæ of rock for several inches in depth ; appearing on the surface like *small black specks* or points, the very largest only $\frac{1}{8}$ inch across. This little fossil occurs along the whole outcrop.

Tentaculites fissurella,† although so small as to be *scarcely preceptible to the naked eye*, is in such vast abundance that it makes *solid*‡ *layers of rock several inches*

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*But in middle New York its *Goniatites* are larger than in any other rock in the state.

† Like the broken point of a fine needle an eighth of an inch long ; but a microscope will show a slit or fissure running down one side about one-third of its length. Towards the blunt end the surface is smooth, but towards the point grooved crosswise into rings.

‡ The least exposure to the weather however breaks it up and crumbles it to a sort of sand.

thick, extending many yards, and apparently many miles; for it is equally abundant at distant localities.

Three small brachiopods and three small lamellibranchs mark the Marcellus in western New York and in Pennsylvania:—*Chonetes* (*Strophomena*) *setigera* with six bristle-like spines along its hinge line;—*Strophodonta* (*Strophomena*) *mucronata*, with its curious system of radiation not from the beak but from an imaginary point above the beak, and with its hinge line extended as end spines;—*Productella* (*Strophomena*) *pustulosa*, with its wrinkled and pustule covered pearly shell easily stripped from its cast;—*Pteronites* (*Avicula*) *mucronatus*, with its lopsided wings and paneled surface studded with short spines;—*Pteronites* (*Avicula*) *laevis*, with its smooth finely lined surface, contrasting curiously and beautifully on the same slabs with the last;—*Aviculopecten* (*Avicula*) *æquilateralis*, as nearly symmetrical as a lamellibranch could be expected to make its shell, and easily recognized by its extremely small wings.

A straight horn cephalopod (*Orthoceras subulatum*) smooth and very sharp at the point, with a crease down the whole length (say 3 inches), and chamber marks (septa) slightly arched on each side of the groove, visible two-thirds of the way from the point to the base, is apparently the only species of Cephalopod in the formation. The pressure of rock upon it has flattened most of the specimens; and the chemical waters percolating through the pyritous black shales have often replaced these shells with casts in iron pyrites, which do not show the septa, but look like bright little marlinspikes.

Two or three univalve shells occur everwhere in the Marcellus, but are indistinct because they have been changed into iron pyrites (Hall, 1843).

The Marcellus in middle New York.

In middle New York the *Marcellus formation* is divisible into an earlier, *lower*, *limy*, *fossiliferous black shale*; and a later, *upper*, *non-limy*, and often almost *non-fossiliferous dark shale*.

The upper shale mass is considerably more than 100 feet thick.

In the lower lime-shales the carbonate of lime has collected into black balls, and flattened masses of impure blackish limestone, with curved wavy and knobby upper and lower surface, and coming to an edge all round. Some of the shales are black and friable on account of greatquantities of small seaweeds or graptolites ; so that they resemble poor coal beds, and have deceived people into making hundreds of trial openings in the vain hope of profitable coal mining.*

Marcellus fossils in middle New York.

The characteristic fossils as given by Vanuxem are *Goniatites expansus*, a whorled shell with the last chambers rapidly increasing in size and the partition line marks on

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*The lower shales make the high hill top east of Marcellus village. At a quarry, the *Seneca limestone* has on it *Marcellus black shale*, 5′; then a layer of very impure limestone, shaly, with a *Lingula* and a small *Orthis;* higher up, another thick layer with broken *Goniatites* and *Orthoceras*.—Between Chittenango and Cazenovia many trial diggings for coal, in black shale contorted by the crystallization of carbonate of lime. *The coal runs in minute veins*, and is therefore not true coal, but a deposit of petroleum which has also blackened the whole slate formation. (At Nettleton's a fault brings the *Marcellus* down to abut against the *Corniferous*. Also many *Goniatites* in the stone fences.) Above Oneida falls the lower shales are best seen ; immediately resting on the Seneca limestone ; impure limestone layers, interrupted, breaking into ranges of balls; over these, two *persistent regular* layers, 3′ thick (which seem to extend as far as Marcellus village in Onondaga county), holding the special Marcellus whorled and straight horn shells described in the text foregoing. Crystals of sulphate of strontia, carbonate of iron, etc., occur in lime balls on the east bank of Chittenango creek near the high falls.—Near Waterville the lower shales are more massive, often contorted, glazed with coaly matter, with specks of coal in the joints and cracks.—At Bridgewater the lower shales are glazed, and little slabs of *coal* are found, rarely more than a few inches long, an inch or so wide, and a quarter of an inch thick. (Here slender Orthoceritites and Modiola are seen.)—At the Cherry valley ashery a series of very impure thin limestone layers, with irregularly rolling or knobby upper and lower surfaces (in fact, agglomerated lime ball layers), separated by friable, pyritous, slaty shale layers charged with smooth fossil branching sea weeds (six inches long and all of one species) rests directly on the *Corniferous*. Over them lies a 5 foot bed of the same sort of limestone. Over this lie more than 100′ of the upper shales, making a cascade. On the opposite side of the valley the limestone layers are seen to be merely ranges of balls. (Condensed from Vanuxem's report of 1842.)

the back of the shell; to this formation.—*Nautilus* (*Goniatites*) *marcellensis*, a huge whorled shell sometimes a foot in diameter. This and the *G. expansus* are found only in the quarries between Oneida creek and Marcellus village, and not in western New York. They are *peculiar to the two upper limestone layers* of the *lower Marcellus shales*.—*Orthoceras marcellense* was a huge straight horn squid which lived with the above two whorled shells and was sometimes *a foot in diameter* (Vanux., 1842, p. 147).—*Leiorhynchus limitaris* is very abundant at certain places and pervades the formation from top to bottom, rising into the bottom layers of the overlying *Hamilton formation*. Because it is especially numerous where the one formation passes into the other the name *limitaris* was given it to express the fact that it marks the top of the Marcellus in Vanuxem's district.—*Lunulicardium* (*Cypricardites*) *marcellense* is also a characteristic species.

The Marcellus in eastern New York.

In eastern New York, the *Marcellus outcrop* turns south and ascends the Schoharie valley, past Cobleskill, sinking slowly to the level of the creek and then returning northward past Middleburg to the north end of the Helderberg mountain.*

It then turns and runs south through Knoxville, Bern and Coeymans; † to the ravine back of Catskill; and so on, past Saugerties, Marbletown and Ellenville to Port Jervis on the Delaware river. All the streams which descend from the Catskill mountains cut across into it, as they leave the foot hill country and turn at right angles to flow along the Mamatoning valley. It is therefore seldom seen, for it is covered with drift and river sands. Its outcrop has been most easily eroded, and now occupies the deepest

* Lime balls are abundant in the lower shales; flattened, cushion shaped masses, from a few inches to 4 feet in diameter, some containing brilliant crystals of *iron pyrites*, and also a little *copper pyrites*. The shales are coal black, and coaly matter is diffused in particles and interlaminated in delicate films.

† Here so black as to be frequently opened in vain for coal. Fossils rare.

valley of the region; is, in fact, buried far beneath the present valley bed.‡

The following *lamellibranch* shells are all that are assigned to the *Marcellus formation* in Prof. James Hall's MS. list of *type specimens* preserved in the State Museum at Albany, and distributed in sets by direction of the Secretary of the Board of Regents of the University of New York, in 1886. They are figured in Pal. N. Y. Vol. V, i.

Pterinopecten dignatus; Actinopteria muricata; Leiopteria levis; Panenka linckleni; Glyptocardia speciosa (*Marcellus* and *Chemung*;) *Lunulicardium marcellense*, Vanuxem; *Lunulicardium fragile*, Hall (*Marcellus* and *Chemung*).

‡The above details are all that can be found in Mather's report of the First District of the New York survey, 1843, pp. 317 to 323. It is impossible to learn how the character of the New York outcrop gets changed to that of the Pennsylvania outcrop.

Chapter LXXXV.

*VIII b, Marcellus in Pennsylvania.**

The Delaware, flowing from the northwest across *Catskill*, *Chemung*, *Genesee* and *Hamilton* strata, turns at Carpenter's point just below Port Jervis † and flows, southwest along the outcrop of *Marcellus*, past Rosetown, Milford, Dingmans, Delaware, and Egypt Mills, to Bushkill; where it makes a sharp S through Walpack ridge, and pursues its course to the Water Gap over the outcrop of *Clinton No. V.*

From Bushkill the *Marcellus outcrop* keeps straight on (S. 60° W.) past Echo lake and Coolbaugh pond,‡ down Pond creek, across Broadhead creek, to an anticlinal point 3 miles west of Stroudsburg; then returns east and circling round Stroudsburg, runs on (S. 60° W) up McMichael's creek. to make another anticlinal point at Sciota. Zigzagging twice, it keeps on (S. 60° W.) past lake Poponoming and Rossland and follows Frantz's creek to Kunkletown and Little Gap, where the creek leaves it (as the river does at

*The Delaware river seems to have flowed in different ages along different lines. At one time it seems as if it turned at Port Jervis, S. E. corner of Pike county, and flowed N. E. to the Hudson river valley at Rondout in the State of New York. Or, it may be that the Hudson river at that time was a branch of the Delaware and flowed from Rondout to Port Jervis. See Prof. White's statements in his Report G6, p. 53.—In the other direction it is possible that before the ice sheet came from the north and changed the courses of so many of the rivers of Pennsylvania by blocking up and filling in their old river channels, forcing them to excavate new ones, the Delaware river, instead of cutting through the ridge at Walpack Bend from the Marcellus valley on the north to the Clinton valley on the south, kept on S. W. down the Marcellus valley to Stroudsburg and so by Broadhead's creek to the Delaware Water Gap. See Prof. White's account of the "Stroudsburg buried valley" in G6, p. 54.

† Matamoras is the village on the Pennsylvania bank opposite Port Jervis on the eastern or New York bank of the Delaware.

‡ These and Pond creek may represent the ancient and now buried channel of the Delaware before the ice age.

Walpack bend) to cut through the *Oriskany* ridge into the *Clinton No. V* valley. The outcrop keeps straight on to Millport and the Lehigh river a mile below Bowman's, and so through Carbon and Schuylkill county to an anticlinal point several miles west of Schuylkill Haven. Returning east it circles round the east end of Summer hill and begins again its W. S. W. course at Auburn, and so on to the Swatara river and the Susquehanna river above Harrisburg.

No continuous section of the formation can be obtained anywhere along this outcrop line of nearly a hundred miles. Its outcrop belt has been eroded more easily than that of any other formation, except the *Clinton*, and therefore has been selected by principal streams, the Delaware, McMichael's, the Aquanchicola, etc., for their channels. From Port Jervis to the Wind Gap, these channels have been filled with Glacial Drift, and only partially re-excavated since the disappearance of the northern ice. Only the top and bottom of the formation rise to the surface on the edges of the outcrop belt. But a few exposures of the middle beds can be found in gorges which the streams have cut since the ice age in their efforts to restore the ancient drainage of the country. From the Wind Gap westward, the country was not invaded by the northern ice, and received from it no covering of moraine; but the Marcellus valleys have become nevertheless encumbered with local drift, partly brought down from the moraine covered area, and partly slid from the bordering ridge of Oriskany and Corniferous on one side and the Hamilton sandstone hills on the other.

Along the Delaware, from Port Jervis to Bushkill, the top of the formation is preserved in the bluffs which overhang the northern bank, to a height of about one-fourth that of the bluffs. The lowest beds appear in one or two places on the New Jersey bank.* From Bushkill to Stroudsburg

* We will see that this characteristic slate pencil splintering up of the Marcellus furnishes the most perfect road metal in various parts of middle Pennsylvania. The geologist could tell his place in the series of the rocks by merely taking up a handful of it from the roadside. But as the Marcellus shares this quality with the *Lower Hamilton*, it is evident that the distinction between *Marcellus* and *Hamilton formations* is a purely arbi-

many opportunities of seeing both the highest and lowest beds are afforded, as the dips are low and the valley wide. Still better opportunities are presented around Stroudsburg, where the formation rolls and spreads over several anticlinals; also along McMichael's creek. But from the Wind Gap to the Lehigh river the dips steepen, the outcrop belt becomes narrow, and Frantz's creek covers it with its wash. At Bowman's station on the Lehigh the formation rises vertically from the underground.

The Marcellus formation has three subdivisions, upper, middle and lower; the upper and middle are persistent; the lower division only appears at two places on the Delaware, but becomes continuous from west of Stroudsburg westward to the Lehigh. The upper and lower states are dark, blue black, sometime black; the middle states are grey; the lower slates (where they exist) very black, in places bituminous, holding thin layers of a kind of coal; not true coal, because there are no underclays, and no remains of land plants.

The *Marcellus upper blue black* or very dark grey beds are not slates but shales. They differ from the overlying *Hamilton* beds which are lighter colored soft sandstones; but they resemble them in the trick which both have of weathering into innumerable small fragments like slate-pencils, which slide and roll over each other down the steep bluffs into the valleys; only, those of the *Hamilton* are coarser grained, and larger than those of the *Marcellus*, which have a fine grain and are slender; both kinds make the finest road metal imaginable; smooth, packing firmly, resisting the wheel tire and drying speedily after a rain.

School slates ought to exist where slate pencils are so abundant although the spontaneous weathering of the strata into pencil-like fragments would hardly encourage much prospecting for smooth durable layers. But, where

trary one, the *Marcellus* deposits being continued into the *Hamilton* age; no reason but their darker color justifying their name; as the deposit became coarser its color growing lighter, chiefly in all probability because fine or mud clay has the faculty of absorbing and retaining petroleum better than coarser or more sandy clay.

the *Marcellus upper* dark strata are brought to the surface by the great Weissport anticlinal, along the valley of Big Creek in Polk township, near the Carbon-Monroe county line, west of Kresgeville, the mining and manufacture of *school slates* was once carried on extensively and only abandoned on account of the expense of transportation and the competition of the Slatington district of Lehigh and Northampton counties.*

The best places to see this upper division of the *Marcellus* is in an almost perpendicular cliff of blackish sandy shales, 200′ high, on the north edge of the Pond Creek Valley, three miles west of Bushkill, at Overfield's, north of Echo Lake. †

For *fossils* the best place is a low cliff on the north edge of the borough of Stroudsburg, where the lower beds of the upper division abound in uncertain species of the genera *Spirifera*, ‡ *Chonetes*, *Orthis and Productus*, with many *Crinoidal fragments*.§

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* G6, 306. There was nothing against the quality of the slates at this quarry; but efforts made to obtain more durable slates for roofing purposes at various places between the county line and Kresgeville proved futile. The *Marcellus* formation does not furnish roofing slates in Pennsylvania equal to those of the Hudson river formation No. III. The cleavage at the school slate quarry dips 50° (S. 79° E.) but the dip of the stratification is obscure. Only the upper part of the formation is brought up by the anticlinal along Big creek ; and the wide valley is covered with local drift as far east as Broadheadville in Chestnut Hill township, and thence eastward to Stroudsburg, by glacial drift. North of Stroudsburg the anticlinal rolls of Walpack ridge spread the formation out into a drift-covered plain.

† Dip 15° to 18° (N. 28° W.). Fossils numerous but too badly preserved to be identified. Thickness of the division *perhaps* 500′ (G6, 229). The same dark shales appear on the main road, three miles east of Bushkill (213). *Very black* shales in this division are quarried for road metal one mile north of Stroudsburg (270). In Hamilton township they make Yeager's falls (15′) in a narrow gorge of McMichael's creek. At Yeager's road metal quarry, a mile further south, they hold many broken undeterminable fossils (286′7). In Ross township, on Frantz's creek below Andrews' cross roads, they dip 35° (N. 25° W.).

‡ *Spirifera (Ambocœlia) umbonata*, the little shell so extremely abundant in western New York, was not seen by Prof. White anywhere between the Delaware and Schuylkill rivers (G6, 116).

§ Fossils in all the divisions of the *Marcellus* throughout this upturned, folded and compressed outcrop, from end to end of it, are only numerous at certain points, and are always badly distorted and broken so that it is scarcely possible to determine their species.

The thickness of the *Marcellus upper dark shales* is not measurable with an approach to accuracy. It may be 500′.*

The *Marcellus middle grey slate* division is also of unknown thickness because always concealed for the most part by the river, and by other streams flowing in drift-filled valleys. Here and there they appear as grey slaty sandstone, or massive sandy shale beds, parted by buff-colored softer shales. Such rocks are seen making a natural dam across the Delaware, half a mile below Matamoras (opposite Port Jervis), dipping 15° to 20° (N. 20° W.), with cleavage planes of 60° (S. S. E.), projecting from two to five feet above low water mark, and interrupted here and there to let the water through.

Such slates rise upon the back of the *Corniferous* from beneath Pond Valley, from Bushkill west to Stroudsburg.† The actual contact of the two formations is not seen, but no *Marcellus lower black shales* appear along here.‡

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*Where the buried Valley of Pond Creek (in eastern Monroe) is a mile wide, and the *Corniferous* on its southern edge rises at 16°, the *Marcellus formation* if it maintained that dip under the whole valley would measure 1300′. If the dip flattens, or there be concealed rolls like those in the Corniferous ridge to the south, the measurement will be proportionately less (G6, 255). On the Lehigh Prof. White makes the whole formation 800 thick (G6, pp. 81–115). Dr. Chance makes it 1200 thick (G6, p. 83). Mr. Winslow makes it —— thick (see Lehigh Valley section in Ann. Report for 1886, p. ——).

†From Bushkill westward the bottom rocks of the *Marcellus* crop out in many places against the upper surface of the *Corniferous* slope of Walpack ridge, but *no black slates* are to be seen; always dull grey, sandy slates, with coarse cleavage, and thin partings of lighter colored shale, giving the mass a sort of banded appearance.

‡How these shales actually lie on the *Corniferous* does not clearly appear. There seems to be always a concealed interval of 3 to 10′, as on the pike (a mile S. W. of Shoemaker's), at J. V. Coolhaugh's, where sandy slate beds 4 to 5 feet thick, parted by light buff layers 2 to 4 inches thick, and cleft 70° (S. E.), are cut in a house cellar, the *Corniferous* limestone rising just across the road, the dip making a 10′ interval. *Contact of Marcellus and Corniferous* can almost be seen half a mile east of Marshall Creek P. O., where Pond creek, 10′ wide, separates an outcrop of blue grey, hard sandy slate from an outcrop of limestone. The slate certainly lies only 3′ or 4′ over the limestone, and probably rests directly upon it (G6, 254′5). At Stroudsburg these same bottom grey bids, lying close above the *Corniferous limestone*, are alternate beds (1′ to 2′ thick) of blue gray shale, and parting beds (3″ to 4″ thick) of yellow grey shale. They are well exposed for several feet just above the *C. limestone*, in the bed of McMichael's creek,

Gray slates of a similar character, higher in the formation, are to be seen around Stroudsburg, and their whole thickness may very well be 500′ or more.*

The Marcellus lower black slate division has a superior claim on our interest for several reasons:—(1), because it was deposited so irregularly over the ancient sea bottom, that along some of its lines of outcrops it is thick; in other places thin; and along many miles absent altogether; (2), because it is so calcareous in some districts as to contain lime balls, and even beds of limestone; whereas in other districts it is almost or quite destitute of lime;—(3), because it pretends to be a *coal formation*, and, in a thousand places has made the most shamelessly delusive promises of mineral wealth both in coal and iron ore to the farming population of our own and other states,—promises which it has never anywhere in the slightest degree fulfilled.

Along the Delaware river, on the New Jersey bank, the black slates appear at two places;—at the futile coal dig-

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foot of Elizabeth street, Stroudsburg. Gray shales here have a breadth of about 500 yards, and their bottom beds at the bridge dip 27° (N. N. W.), which, *if continuous at that rate*, would make the thickness of the beds, as exposed to view, say 450′. At the contact on McMichael's creek, where the E. Stroudsburg axis crosses the road between Col. Norton's and the bridge, the blue gray slate and limestone are planed off and groved by ice, and their edges are only two or three feet apart (G6, 267). Just east of Kunkleville, Hamilton township, an interval of 20′ is conceded between dark grey hard sandy shale and the limestone (p. 287).

*Such bluish gray shales are finely exposed under the Stroudsburg iron bridge, where McMichael's creek has left its old channel and cut a deep new trench through them; dip 27° (N. 20° W.); cleavage steep (S. E.), Here are seen 50′ of hard, blue gray slate beds (3′ to 5′), parted by light drab layers (3″ to 5″), the top of the Corniferous limestone lying 40′ to 45′ underneath. The same strata are well exposed in a D., L. W. RR. cut just below E. Stroudsburg station, apparently horizontal. Also in road 1¼ m. W. of Stroudsburg, opposite Col. Norton's; cleavage distinct and regular (G6, 269, 270). Also at Wickoff's mills, 1½ miles above Stroudsburg, where Broadhead's creek has cut a new, long, deep channel for itself, full of pot holes and odd looking prominences of slate in its bed. The mill dam is a rib of slate, dip 10° (N. 30° W.). in some places, horizontal in others, and exposed for 300 yards; cleavage to the S. S. Also in Hamilton township, where the southern branch of McMichael's cuts through the broad terminal moraine drift, and occasionally into projections of slate belonging to the surface of the buried valley.

gings two miles above Milford ;* and at A. B. Van Noy's opposite the south end of Shabacong island,† where *nearly jet black pyritous very fossiliferous fissile slates* are exposed for 300 yards along the low river bank, and in the river bed. The sulphurous iron water covers the outcrop with rust and has made a sort of iron ore bog along the edge of the river. Where the slates have been dug into by some one who supposed they contained gypsum, the following fossil shells are in abundance :—*Tentaculites fissurella ; Ambocœlia umbonata ; Leiorhynchus limitaris ; Discina minuta.*

It is hardly possible that this outcrop of black slate should run for miles under the river sand.‡ Their deep erosion has probably determined the course of the river. And yet when the river at Walpack Bend (Bushkill) abandons the *Marcellus* outcrop to make its bed in *Clinton* rocks, there is not a sign of these black slates (as we have seen above) upon the *Corniferous* along Pond Creek valley; nor in the Stroudsburg district. They do not reappear until we approach the Hamilton-Ross township line.

This is the place where the underlying *Corniferous* and *Caudagalli* begin to thin out westward, and the two phenomena must have a close relationship ; especially in view of the fact that the New York outcrop of black slate is very calcareous.

Approaching the Ross-Eldred township line the *Marcellus lower black shales* become so bituminous that several expensive searches for coal have been made.§

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*G6, 195.

† Dr. Kitchell's report of 1854. Prof. Cook's Geol. N. J., 1868, p. 167.

‡ As under the flats west of Hornbeck's mills ; and under the drift islands ; but it may be deeply buried.

§ The *black shale* at Bonser's, Ross township, looks like *poor anthracite coal.* Entries from the south bank of Frantz's creek into the north foot of Dodendorf mountain (*Corniferous* and *Oriskany*) show *20′ of this black slate, through which are scattered thin layers of coaly material : Fossils,* distorted and indeterminable ; dip very steep (N. W.) ; bog iron ore on the upturned edges of the slate, under the soil ; *Oriskany* drift covers several hundred feet of the *Marcellus belt.*—At Kunkletown, bottom slates *very black,* with thin plates of *impure anthracite,* blazing in a fire and leaving much slaty ash ; bog ore on the upturned edges under the soil (G6, pp. 274-5, 301-2).

CLV

No. VIII b, Marcellus in Perry Co.

Plate X. 158 F2

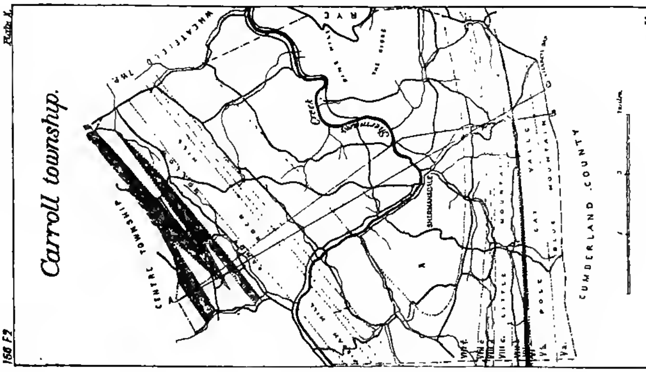


Plate VIII. 92 F2

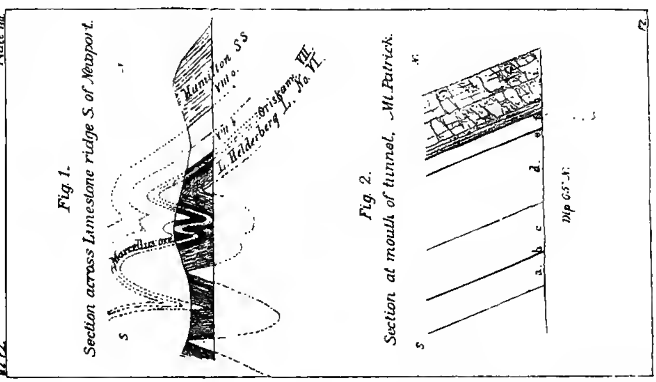
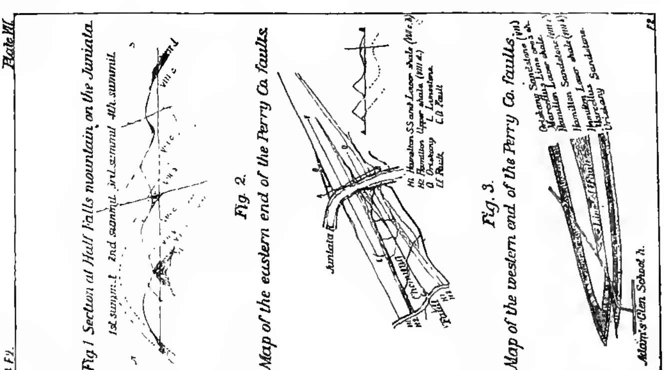


Plate VII. 84 F2



Bogs of iron ore have been deposited in many places by the pyritous drainage from the black slate. They lie between the outcrop of the slates and the local drift covering at the surface. There are no beds of iron ore in the formation. Digging for such will always fail of success. But these bogs can be, and have been, mined for *mineral paint* for barns, bridges, carriages and cars. This has been done a half mile west of Sciota, Hamilton township ; a mile above Sciota on Little McMichall's creek ; just west of Sand Hill P. O.; at Bonser's at Kunkletown.*

VIIIb. Marcellus at the Lehigh.

Approaching the Lehigh, the *Marcellus outcrop*, turned up vertical, and even overturned to a reverse dip of 70° and even 40° (S.), runs along the elevated vale behind the Stony ridge, between it and the Hamilton, Chemung and Catskill high ground. At Millport the *upper dark slates*, here slightly overturned, run along 2500′ north of the Aquanchicola creek. They exhibit good cleavage planes and are hard enough to work. Two quarries have produced *roofing slates* of fair quality. The whole formation seems to measure more than 1200′; but it is so crushed, that the measurement is doubtful.†

VIIIb. Marcellus in Perry Co.

Along the Kittatinny (North) mountain, from the Susquehanna Gap at Marysville, westward, through Rye township, the Marcellus formation is thin, and its black shales wanting. Its outcrop runs along the south foot of Little mountain to Oak Grove, there turns, and runs northeast at the north foot of Pisgah hill, Rocky hill and Dick's ridge, past Montebello, between which place and the Juniata it is swallowed by the Perry county fault.‡

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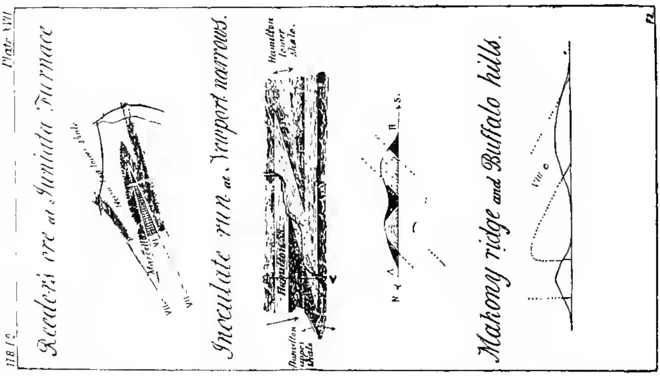
*G6, p. 114, 287. On Frantz's creek the bog rests on a steep slope.

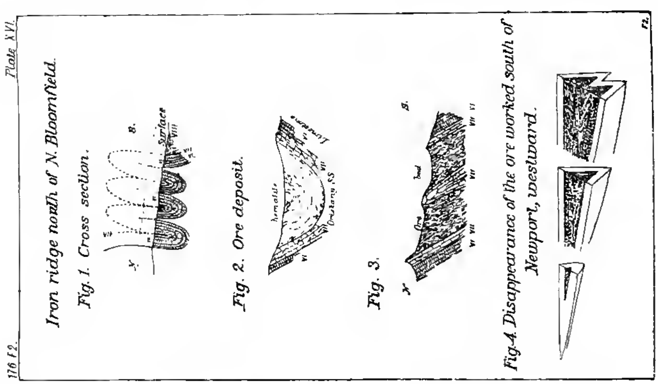
† Chance's report in G6, p. 355. The position of the quarries is shown on the Contour map of the Environs of the Lehigh Water gap, in that volume of the reports.

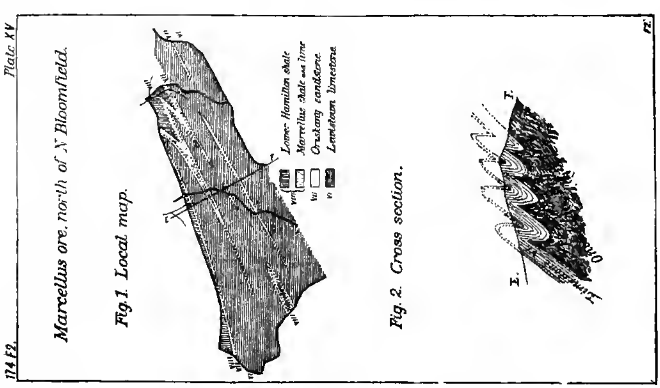
‡ The colored geological map of the county in Report F makes no distinction between the Marcellus shales and Hamilton lower shales, uniting them in one belt of dark Vandyck brown. The limestones next the Oriskany,

CLVI

No. VIII b, Marcellus Iron Ore in Perry Co.







On the Juniata below Baileysburg, the Marcellus comes up (from the south) in Half Falls mountain, turns over the great anticlinal, and sinks again (northward) under the Buffalo Hills Hamilton range, to the bottom of Buffalo creek and mountain basin, (13,000′ deep) and rises to the surface again in Wild Cat ridge.

From Half Falls mountain westward, one fork of the outcrop runs along the north foot of Mahanoy hill past New Bloomfield to Elliottsburg, and then zigzags around its west end, and the ends of Crawley's hill, North Furnace hill and South Furnace hill, and is swallowed by the fault, The other fork of it runs at the south foot of the Buffalo hills, twenty-five miles near Andersonburg (with two little zigzags at Sandy Hill) and then returns east at the foot of Raccoon ridge (with three little zigzags) past Donally's mills, to Millersburg on the Juniata, (22 miles), and of Wild Cat ridge, 9 miles further, to within 3 miles of the Susquehanna. Here it turns sharply over the Tuscarora mountain anticlinal, at the south foot of Turkey ridge, to the Juniata; from which it runs on in the same direction (north of Tuscarora mountain) the whole length of Juniata county, into Fulton, where it is swallowed by the great Cove fault, only to reappear at the surface at the Maryland state line.

In Perry county alone we have 130 miles of Marcellus outcrops; and should have adequate opportunities for acquiring a knowledge of its character; but its soft nature has made its erosion easy, and it occupies the bottom of a continuous deep narrow valley, or series of vales, separating the Limestone outcrop ridges from the high Hamilton sandstone outcrop ridges everywhere.

The *Marcellus* vale is therefore thickly floored with local drift from one or other, or from both its bordering hillsides; and even where streams cross it, the slates are seldom seen.*

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which have been described in foregoing chapters under the name *Corniferous*, but which Prof. Claypole and others prefer to call *Marcellus limestones*, are also included in the same color belt.

*In Spring township are the best exposures of *Marcellus black slate* in the county; as, at the *road-gravel quarry* near Little Germany, on the Elliotts-

CLVII.

No. VIII b, Marcellus iron ore and limestone.

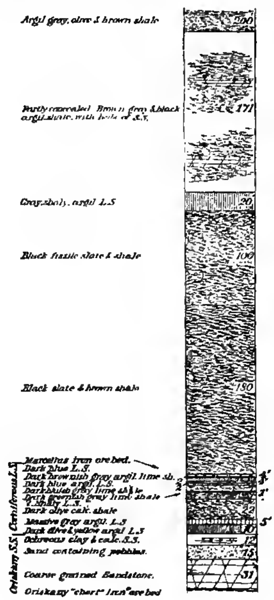
In Perry county.

Tudor's quarry section.

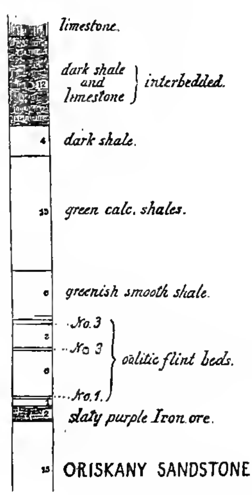
Rice's quarry section.

In Huntingdon Co.

Section of the Oriskany SS. and Marcellus slate, showing position of iron ore beds, at Three Springs and Saltillo in Huntingdon Co. Pa. Page 223.

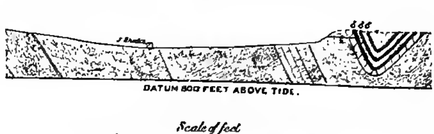


Marcellus limestone.
Centre Mills section.



In Mifflin county.

Rhodes' ore bank.



It is a mass of thin layers of very dark, or nearly black, smooth slaty shale (here and there slightly sandy), without fossils, or with very few discoverable, nowhere more than 120′ thick. The bottom beds are very ferruginous, pyritous, and black; but the black color diminishes in intensity upward. Its top beds have no distinct upper limit, but pass gradually into the grey shale bottom division of the *Hamilton formation*.

Fossils in the *black Marcellus shale* are so rare as hardly to be found. One species however, the minute *Sporangites* (*seed vessels ?*) * abounds in the lower beds at almost every exposed outcrop in Perry county.

The black soil is poor; but the black slates (as on the

burg road.—At the west end of the Mahanoy ridge basin, *the lower more solid beds are calcareous*, but furnish no fossils except little seed vessels (*Sporangia*). The whole formation is exposed between the school house and saw mill.—Nearly the whole formation of black slate is again exposed near Mr. Rice's house; together with the underlying limestone beds. Here 80′ of black slate show, and some beds are concealed under the road bed, making the total black slate formation in this part of the county, not 200′, but say 100′. Here can be plainly seen the gradual change of color upward: black shales at the base, rusting to an ochreous color; covered by beds less and less rusted (i. e. less and less pyritous); then pink; then gray; insensibly ascending into the grey Hamilton shale formation without a perceptible plane of division anywhere (F2, 342).

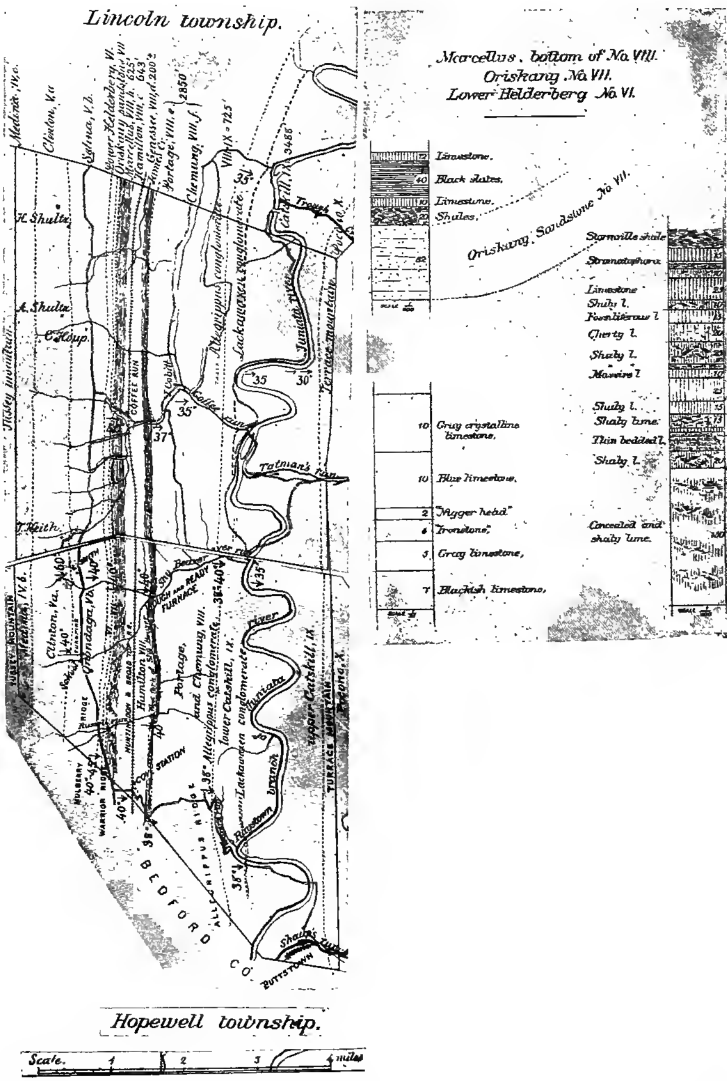
In Centre township the best exposure of Marcellus black slate is in the field adjoining Barnett's rocks, south of New Bloomfield: slates vertical; no fossils.—On Dorran's run, at the cross roads between Buffalo hill and limestone ridge, an ore digging has thrown out black slate with a few fossils.—At the old Juniata ore banks (2 miles east of New Bloomfield) black shales dip both ways (basin) on both sides of the cross road (F2, 196).—In Miller township, heaps of the shale surround the ore diggings at the north end of Pine Grove narrows.—At Montebello narrows, slightly overturned (95° S. S. E.) the shale is well shown. Here a hard, close-grained, sandstone bed, (1′), not elsewhere seen in the county, lies at the base of the shales (F2, 269). It suggests a possible explanation of the grey slate exposures *on the Corniferous* at Stroudsburg, described in the chapter on the Delaware river outcrop.

In Madison township good exposures of the black shale can be found on the low anticlinals in many places between Bixler's mills and Sandy hill, where a strong *Sulphur Spring* (H. Kepner's) issues. The underlying limestone beds (described in the chapter on *Corniferous, VIIIa*) make a good show along the roadside (F2, 263).

*Dawson, 1853, in Canadian Naturalist, VIII.—Rhizocarps in the Palæozoic period, Dawson, quoted in F2, 65.—Also found in the Ohio *Marcellus* by Orton; Proc. A. A. S. 1882, 1883.

CLVIII

No. VIII b, Marcellus outcrop and sections in the southwest part of Huntingdon Co.



Delaware) make the best of road-metal; witness the hard, smooth, dry roads at Little Germany and Centre mills.

Coal has been foolishly dug for in the black slates at the west end of Mahanoy ridge in Spring township; although the whole formation from top to bottom is exhibited between the school house and the saw mill, and any coal bed which existed must have been known from the first settlement of the country. Many holes have been dug; and it is reported that a seam of coal 3″ (inches) in thickness was found in one of them.* But no *workable coal bed* will ever be discovered in this black slate formation anywhere in Pennsylvania; for, not a stem or leaf of any coal-making plant can be found in it. Whatever vegetation grew in that age on distant lands could only send its pollen and pollen cases out to sea on the wind, or float them into the sea on the surface of great rivers. Moss vegetation could not flourish on a sea bottom. However difficult it may be to account for the little streaks of consolidated coal-like matter found so commonly between the lower black slate layers, it is quite certain that they do not resemble true coal beds in any respect, having neither white under-clay floors, nor fern-leaf shale roofs.

Before advancing up the Susquehanna river to the *Marcellus* outcrops in Northumberland county it will be well to show how the black shale lies in Perry county in reference to the under and overlying formations:

Hamilton	*upper shale*, varying from 200′ to 300′ *middle sandstone*, varying from 500′ to 800, *lower grey shale*, varying from 300′ to 500	1200′±
Marcellus	*black shale*, varying from 80 to 120′ *iron ore bed*, varying from 2′ to 14′	100′±
Corniferous	*limestone*, varying from 10′ to 30′ *lime shale*, varying from 20′ to 40′ *iron ore*, varying from 2′ to 3′	100′±
Oriskany sandstone, varying from 0′ to 20′, ...		. 20

False Coal beds in the Marcellus.

The shales of this formation are so black that it is not to be wondered at if many persons have spent money in

* F2, 342.

searching for coal beds; and they are so charged with carbon that some specimens will flame and smoke when laid on a blacksmith's forge fire. But no good coal, and no workable bed of even poor coal, has ever been found in the formation, nor is likely to be. For the outcrops are so long and broad that any really good coal bed would have been discovered long ago. The best exhibition in the State has been in Perry county where very thin coal crops are seen crossing the bed of the Juniata. Many years ago I was called to examine quite long gangways driven at much expense into the hillsides rising from the river bank; but the largest of these "coal beds" was only about one foot thick, gave a worthless fuel had no underclay, and therefore was not a true coal bed; Prof. Claypole's report of Perry county mentions such openings in several townships, all expensive and all ineffectual. In other counties of the State the same story has been often repeated.*

Not only in the Marcellus, but in the overlying Hamilton shales and sandstones similar false coal beds occur, some of them several inches thick, which have deceived people with hopes of gain, and confused the popular mind respecting the age of the Coal Measures.

Fault and Crush in Centre county.

An interesting section of Hamilton rocks is given in Mr. d'Invilliers' Report on Centre county, T4, 1884, p. 300, for a reduced copy of which see middle of plate CLXX, page ——— above. The exhibition is made on Marsh creek in a quarry 1½ miles W. N. W. of Eagleville, the spectator looking N. 70° E. The Hamilton sandstone beds lying flat, but waving over the lower shales are dropped on a fault slope (hade) of 22° against vertical red and olive shales. A sharp synclinal and a sharp anticlinal north of the fault

*See Report F2, p. 108.—W. Smith bored several shallow holes around New Germany, Perry county, and struck in one of them "a bed of coal three inches thick." A tunnel 30′ or 40′ long was driven across the measures without showing a trace of coal, F2, pp. 343. Near Laurel Grove a like vain search was made. But, in a word, scores of such Marcellus coal prospectings have been made throughout middle Pennsylvania, involving a great waste of money.

show the great pressure to which all the measures have been subjected. It must be kept in mind that this is behind (N. W. of) the Bald Eagle mountain, and is merely a part of the tremendous plunge into the underworld which all the Palæozoic formations here make northwestward beneath the Allegheny mountain edge of the Coal Measures of Clearfield county; the softer formations suffering most in the general movement.

CHAPTER LXXXVI.

The Marcellus iron ore of middle Pennsylvania.

The *Corniferous limestone*, in its thinned and altered condition west of the Susquehanna, is still of importance as a guide to the *Marcellus ore*, lying either directly upon it, or within a few feet of it in the overlying *Marcellus black slate.**

In Perry county, Oliver township, south of Newport, on the Juniata, the old mine of Juniata furnace was described by Dr. Henderson in 1839, as a bed entirely composed of brown cellular hematite ore, 8′ to 10′ thick, lying between black slates, a few feet above the top of the limestone, and 100′ above the top of the Oriskany, dipping 45 N. W.†

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* Mr. B. S. Lyman, in his paper on the Geology of the Low Moor iron ore of Allegheny county, Virginia, read before the Am. Inst. Min. Eng. Pittsburgh meeting, February, 1886, gives good reasons for opposing the name *Oriskany* applied to it by W. B. Rogers, I. L. Campbell, and others, and for considering it the equivalent of the Marcellus iron ore to be described in this chapter. The Upper Helderberg strata are wanting at Low Moor; so that the Brown hematite ore bed, about *fifteen feet thick*, is separated from the Oriskany by only 5′ of flint and 20′ of clay. He gives Geo. T. Wickes' section from the black slate down to the Medina on p. 2, and map, and cross section on p. 3 showing excessive complication like that of the Lewistown valley

† Geol. Penn. 1858, pp. 357. In 1839 this was the only opening on the Buffalo hill range in Perry county. Since then various ranges of outcrop have been prospected, and some extensive mines established; such as the Reeder mine, and the Clauder mine; which last is now the most extensive. Two or three distinct and regular beds run through a mass of white clay; other irregular strings of ore also penetrate the clay: the ore being the ordinary wash, lump, honeycomb, and pipe ores so well known in Pennsylvania as to need no description. Professor Claypole describes vertical beds of white and black clay 15′ or 20′ thick through which are thickly scattered lumps of brown hematite. There is an impression among the miners that where the ore is abundant the underlying limestone beds are wanting; and that where the limestone formation is in full force there is little or no ore. It is also asserted that in the absence of the limestone formation the Marcellus ore and clays (12′ to 20′ thick) lie directly on the *Oriskany sandstone*, This only shows the confusion of ideas which has prevailed respecting the Oris-

Much of the ore mined in the little troughs of Miller, Centre and Spring townships, Perry county, is probably ore developed in the lime-shales under the limestone; the *Marcellus ore*, above the limestone, being either thin, wanting, or swept away; for, in the northern range of townships in Perry county, along Wild Cat ridge between the Susquehanna and Juniata, and along Raccoon ridge from the Juniata westward, the outcrop of the *Marcellus ore* is wanting.* It appears, however, in the synclinal prong of Oriskany 1½ miles N. E. of Ikesburg. No *Marcellus ore* shows along the frequent exposures of limestone in the ridges between Andersontown and Coneococheague mountain in Madison township; but along the northwest base of Mahanoy ridge a vertical outcrop of it extends continously for miles; the ore being both hematite and carbonate; that is, both altered and unaltered; and lying above the *Oriskany*. Around Perry furnace in Spring township both the ore and the limestone appear. The old ore bank a mile east of Elliottsburg, at the end of Mahanoy ridge, was in brown hematite. The outcrop does not appear in the Warm Springs neighborhood of Quaker hill, along Sherman's creek. But to the southeast in Polecat valley, at the foot of the Blue mountain, two or three miles west of Sterrett's Gap, and from the westward to Oak Grove, it crops out frequently in its usual condition, but only 50° above the *Oriskany*. At the principal ore bank at Oak Grove the bed is about 5′ thick, dipping 50° S. E.

Marcellus Ore in Juniata county.

The great synclinal valley of Tuscarora creek extending through Juniata county and southern Huntingdon into

kany ore horizon and the Marcellus. The two horizons are separate and distinct, and need not be confounded by a careful field geologist; especially where the lime-shales under the limestone are in any considerable thickness. It must be remembered however, that the lime-shales themselves have a pronounced tendency to develop ore (as is strikingly shown in Huntingdon county), and it is the ore of these shales resting sometimes on the Oriskany which is mistaken for the regular Marcellus ore, the place of which is always above the limestone, and beneath the black slates.

* Geol. Penn. 1858, Vol. I, pp. 355–357.

Fulton is bordered on each side by *Oriskany* ridges, carry- *Corniferous* lime shales and limestone, and on top of the latter the *Marcellus ore bed;* but only at the west end of the valley, namely, in Huntingdon county.* In other words, the Marcellus ore bed is absent or so thin as not to be recognizable throughout Juniata county, as we have seen it practically absent in the northern townships of Perry county. We will see it in Mifflin county mined near Lewistown and McVeytown, and also in the Aughwick valley of Huntingdon. But it is not to be seen towards the east and north in Snyder, Union, Northumberland, Montour and Columbia. It is evident therefore that the *Marcellus ore bed* may be regarded as originally deposited along a belt, stretching east and west, practically confined to the same latitude as that of the *Corniferous belt;* but on account of the enormous erosion of Middle Pennsylvania, which has left us the Lower Devonian rocks only in the two synclinals of Perry county, and in the two long narrow synclinals of Juniata and Mifflin counties, we shall never be able to restore the original geographical area occupied by this important iron ore deposit.

To understand the *Marcellus ore bed* we must go to the mines at Lewistown and McVeytown in Mifflin county, and about Orbisonia in Huntingdon county.

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*In the Tuscarora valley *Corniferous* limestone, and underlying lime shales, and the *Oriskany* sandstone, are traceable along the two opposite outcrops, in the same order and general condition as in Perry county; with an absence of the ore in Juniata county. A few details will suffice. At the Juniata-Huntingdon line, where Tuscarora valley becomes Little Aughwick valley, between Tuscarora mountain and West Shade mountain—and where the *Corniferous* limestone is only represented by a few layers of dingy blue argillaceous limestone at about 100′ above the Oriskany—the *Marcellus ore bed* begins to show itself, east and west of Shade gap; lying in the Marcellus black slate, a few feet above the limestone. It was opened fifty years ago at Shade Gap as a bed of blue argillaceous carbonate of iron incrusted with brown hematite from 2′ to 4′ thick Thus it runs past Fort Littleton into Fulton county, and returns in the Great Aughwick valley to the Juniata. On the southeast side of the valley from Beall's mill to the gap at Waterloo the shales and limestone dip 45° N. W.; the limestone being well exposed at the Waterford bridge. At Waterloo gap the ore of this southeastern outcrop begins to make the same show on the surface as on the northwest side of the valley.

Marcellus ore in Mifflin County.

In the Mifflin county mines it is plainly seen that the *Marcellus iron ore bed* is essentially a bed of *pyritous carbonate of lime and iron*, only weathering into brown-hematite iron-ore along its outcrop; and that it may be regarded as a natural transition from the underlying limestone to the overlying black slate. Unlike the brown-hematite ore-beds of No. II, and of the Ferriferous limestone of the coal measures, it is as persistent and regular a part of the Devonian series of deposits as any other stratum. In other words, it is in no sense a local deposit, found here and there in holes, pots, or pockets of the limestone, and produced by subsequent chemical solution and precipitation; but on the contrary, an original deposit of carbonate of iron and lime spread widely upon the ancient sea bed. Although thus continuous and persistent, it is naturally variable in thickness; sometimes 10′ or 12′ thick; occasionally even thicker; sometimes diminishing to a mere film; its outcrop sometimes running for a long distance of even size, and then suddenly thinning away almost to nothing.

For many years past profitable ore-banks have been worked along its numerous outcrops; but in all cases the good ore of the bed at the surface only descends to depths varying from 20 to 50 yards; then changes to a poor ore, lean and sulphury; and finally to a highly pyritous black lime-clay.

That the good ore is not an original but a secondary product produced by percolating waters is proved by the occurrence of masses of bastard ferriferous limestone still remaining in the body of good ore; for these are evidently relics of the original bed which have escaped the change into good ore. The cause of the change is to be found in the sulphuret of iron (pyrites) universally distributed throughout the original deposit. Rain water has changed the sulphide of iron into sulphate of iron (copperas) and carried it off in solution, together with the carbonate of lime; the carbonate of iron being also decomposed, the carbonic acid being carried off, leaving nothing to represent the bed but the iron, highly oxidized and hydrated. This chemical process is still going on; and the depth to which it can reach in any locality depends upon the plane of underground drainage; being deepest where the bed crops out near the top of a ridge (Oriskany); and shallowest where the outcrop is cut into gaps, or runs along low ground. Tunnels have been driven horizontally to take a deep hold of the bed turned up at an high angle; and some of these tunnels have struck the bed below the line of underground drainage where it is in its original worthless condition; while overhead there is an abundance of good ore. In prospecting for this Marcellus ore it is only necessary to remember that a trial-shaft which throws out black shale must be above the ore; a trial shaft which throws out green shales or limestone must be beneath the ore; in other words, the ore bed is to be found between the underlying *Corniferous limestone* and the overlying black *Marcellus shale.*

The Lewistown valley is traversed lengthwise by a number of sharp anticlinal and synclinal folds.* Between Logan's Gap and the Water works the general basin is crimpled into four sharp narrow troughs (see section F, 48). On the section line from Lewistown to Jack's mountain the two troughs next to Lewistown are deep enough to take in the *Marcellus*, and consequently the ore-bed, and the limestone, and shale, between it and the *Oriskany*.†

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* See the map of Huntingdon county in Report T3.

† The first little trough north of Lewistown is on the south slope of Prospect rock (an outcrop of the *Oriskany*) back of Lewisiown, affording a superb view of the whole Juniata valley. The south dip at Prospect rock is 63°; the opposite north dip further down the hill slope is 47°. The two ore-outcrops are here 300' apart, and the ore basin is only 250' deep.—The second or Dry Valley trough, on the high land back of the Prospect rock, has a south dip of 80° and a north dip of 58°; distance from outcrop to outcrop of ore, 700'; depth of ore at the bottom of the trough 500'.—The third trough (in Ferguson valley), with dips of 50° and 40°, contains only the *Corniferous shale.*—The fourth wide and shallow trough, running along the foot slope of Jack's mountain (along the north side of Ferguson valley) has preserved nothing above Clinton No. V.—These two last named troughs all have mines only along the outcropping Clinton fossil ore beds.—From the Prospect-rock trough southeastward, past Lewistown and across the river to Stone mountain, the Clinton rocks rise to the south; consequently the *Cor-*

In the Lewistown section *the Marcellus ore bed* overlies 40′ of Corniferous limestone, 53′ of dark shales, 40′ of clay and 110′ of Oriskany sandstone. It therefore overlies the Oriskany by 133′.

At *Moore's ore bank* on the southeast dip of the Squaw Hollow synclinal 3 miles from Lewistown, worked by the Logan Iron and Steel Co., the ore is a brown hematite, the carbonate not having been reached at a depth of 82′. The bed contains from 3′ to 6′ of ore; and in one place is said to be 16′ thick, in another only 2′; starting down at the outcrop with a gentle southeast dip, gradually increasing to 90′ at the depth of 40′; then overturned to 80° N. W. at the depth of 82′. The ore analyzed: iron, 44.7; sulphur, .008; phosphorus, .165; insoluble residue, 19.95; structure somewhat laminated, part of it beautifully stalactitic. The distance here down to the Oriskany is about 100′.

In the same basin a mile northwest from Lewistown the bed was found workable only 50′ down; carbonate ore imbedded in clay then coming in. The carbonate ore is hard, compact, conchoidal, steel-gray, and analyses: protoxide of iron, 48.857; sesquioxide of iron, 0.825; bisulphide of iron, 0.262; alumina, 2.240; protoxide of manganese, 1.625; lime, 4.536; magnesia, 0.569; phosphoric acid, 1.314; sulphuric acid, 0.133; carbonic acid, 32.650; water, 0.368; organic matter, 0.360; insoluble residue, 6.410; total, 100.149; representing: iron, 38.700; sulphur, 0.192; phosphorus, 0.574.

The clay in which the ore is imbedded, or into which it turns, analyses: Silica, 76.100; alumina, 10.040; protoxide of iron, 3.493; bisulphide of iron, 0.043; lime, 0.683; magnesia, 1.419; sulphuric acid, 0.151; alkalies, 2.460; water, 5.390; organic matter, C.110; total, 99.889.

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niferous and *Marcellus* can be found only along the center belt of the Lewistown Valley, running southwestward past Strodes' mill, McVeytown and Mt. Union to Orbisonia. But about 6 miles southwest of Lewistown the Chestnut ridge anticlinal of Clinton rock rises, runs on across the river, and dies down again opposite McVeytown. The *Marcellus ore* (described in Chapter VII, Report F, p. 75–82) is mined along the central basin between this Chestnut ridge anticlinal and Jack's mountain, viz. Moore's ore bank; Minehart's ore bank four miles southwest from Lewistown; and the McCoy and Ross banks near McVeytown (F,92, 93).

The brown hematite ore containing cavities filled with the clay, taken from near the outcrop in the shaft, analyses:—Sesquioxide of iron, 62.143; alumina, 3.795; oxide of manganese, 0.651; lime, 0.722; magnesia, 0.360; phosphoric acid, 1.362; sulphuric acid, 0.053; water, 11.390; insoluble residue, 19.690; total, 99.166; representing:—Iron, 43.500; sulphur, 0.021; phosphorus, 0.595.

The section from McVeytown to Jack's mountain shows four closely compressed troughs.* In the three troughs back of McVeytown which hold the *Marcellus iron ore bed* it lies 108′ and 110′ above the Oriskany sandstone.

At the *McCoy ore bank*, on the south dip of the first trough, the bed is 2′ thick at the outcrop; and from 3′ to 5′ thick near the sand mine.

At the *Ross ore bank* on the southeast dip of the second or Squaw Hollow trough, 1 mile from McVeytown, the outcrop is 350′ above water level in the gap. A tunnel, 75′ above water level, struck a brown hematite bed, 3′ to 5′ thick, after passing through 28′ of alternate beds of black limestone, shale, and carbonate ore, each 8 to 12 inches thick. In the four years from 1870 to 1874, 40,000 tons of ore were shipped from this mine. The workings are extensive and affords one of the best opportunities for studying the underground character of the whole deposit; the intimate relationship of the ore beds to the limestone and shale beds; their alternate regular deposition; their innumerable irregularities in detail; and the chemical change of carbonate into limonite at drainage level, varied by circumstances which it would be hard to discover.†

* In the one next McVeytown (McCoy's), with dips of 65° N. W. and 74° S. E., the two ore outcrops are 300′ apart and the ore descends 300′.—In the second (Ross's), with N. W. and S. E. dips of 75°, the ore outcrops are 300′ apart, and the ore 200′ deep.—In the third (Dull and Bradly's), with dips 90° N. W. and 70° S. E. the ore outcrops are 150′ apart and the ore 200′ deep.—The fourth basin at the foot of Jack's mountain holds nothing higher than No. VI.—At Mount Union, the Juniata valley merges into Aughwick valley, which is its continuation through Huntingdon into Fulton county.

† For example:—About 145′ above the creek, that is 200′ beneath the highest outcrop on the hill, in an entry driven westward, the ore bed varies from 3′ to 7′, and contains no carbonate ore; but in the breasts the carbonate changed to limonite. In another level, 275′ above the creek, much good ore was mined, with a breasting from 75′ to 100′. The lowest gangway, 50′ above

The three kinds of ore in this mine analysed as follows:—1. The uppermost, compact, argillaceous, light brown, limonite, yielded : iron 42.500 ; sulphur, 0.044 ; phosphorus, 0.078 ; insoluble 23.890.—2. The next lower blue black, hard, compact carbonate ore, with a hematitic crust and conchoidal fracture, containing numerous crystals of pyrites, yielded :—Iron, 42.500 ; sulphur, 0.260 ; phosphorus, 0.135; insoluble, 3.390.—3. The lowest and main body of the deposit from water drainage level downward to the bottom of the trough, was carbonate ore of various shades of black, laminated, conchoidal, exceedingly hard and compact, with surfaces somewhat encrusted with botryoidal brown hematite.

At the *Dull and Bradley ore bank* on the southeast dip of the third trough back of McVeytown, on high ground sloping both ways, the bed is from 3′ to 5′ thick, dipping 50°, excellent limonite for 50′ or 75′ down.*

This third trough runs westward down Long Hollow to Mount Union, and along its center line runs a low ridge of Oriskany holding a little trough of Marcellus ore, as at Rhodes' ore bank. But the outcrop is slight and the thickness unknown.

At Mount Union, where the Juniata river issues from Jack's mountain narrows, and crosses the Lewistown valley to Black Log mountain, a carefully measured section was made. At the top appears the bottom 30′ of *Marcellus black slate;* 72′ beneath it lies the top of the Oriskany sandstone (95′ thick); but the *Marcellus iron ore* is not seen in the concealed interval.†

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the creek, driven west, found the alternating beds of lime shale and carbonate becoming a solid mass from 24′ to 28′ thick. The upper limit of the black ore was very irregular ; turning at various heights into gray carbonate ; and still higher, into brown hematite. At one place the gangway went through a cone of black carbonate which fell and crushed the gangway, requiring the excavation of 1400 tons of stuff before proceeding further.

* Good specimens of this compact limonite with a small admixture of ochreous iron ore yielded :—Iron, 51.900 ; sulphur, 0.033 ; phosphorus, 0.231 ; insoluble, 8.970. One of the specimens was a broken geode, showing the chemical changes which go on in the bed.

† The dip is 25° S. E.; increasing southwestward (up Aughwick valley) to 50° and 55° ; and then decreasing to 35° or 40° at the south end of Jack's mountain.

Marcellus ore in Huntingdon county.

In Huntingdon county, Chestnut ridge, which is an outcrop of *Oriskany sandstone* from Mount Union southward to the end of Jack's mountain, is gapped seven miles from Mount Union (five from Orbisonia). Here the Oriskany is seen to be from 125′ to 140′ thick, carrying its own brown hematite ore near its base (Lane's ore bank). The Corniferous shales over it are about 80′ thick and exhibit a good deal of their own scattered ore upon the surface.

From this gap onward the *Marcellus ore bed* has a good outcrop.

At the *Logan farm bank*, 2 miles southwest of the Lane, a shaft 70′ deep at the end of an old open cut got at the surface a semi-carbonate ore, changing downward into black clay; the bed showing 4′ of ore, and analysing: iron 35.500; sulphur 0.480; phosphorus 0.081; insoluble 14.790; a light gray compact clay ironstone.

At *Hick's ore bank*, half a mile southwest of the Logan, the bed shows 6′ of brown hematite; cellular, the holes mostly filled with ochreous ore; analysing: Iron 47.500; sulphur 0.013; phosphorus 0.111; insoluble 14.100.

At the *Stewart ore bank*, $1\frac{1}{2}$ miles southwest of the Hicks, the bed was open cut 50 years ago. In 1873 two shafts, 65′ and 80′ deep, with a gangway, found 6′ of brown hematite; with a little carbonate at the bottom of the deep shaft.

From this south westward the outcrop is marked by good surface shows.

In the old *Fleck* openings the bed is said to have been 12′ thick. A shaft in 1875 found honey comb ore covered with 2′ to 4′ of clay, holdings cattered balls, and over the clay alternate layers of Marcellus brown and black shale.

The Three Springs fault throws the Marcellus ore bed 1400′ to the east in the north wall of the fault, (F, p. 180). The colored map of the fault shows this. The colored map of the Orbisonia district shows the run of the outcrop in front of Black Log mountain. The colored maps accompanying the cross sections of Report F. show how it turns the south end of Jack's mountain.

Aughwick valley, between Jack's mountain on the northwest and Blacklog mountain on the southeast, is a broad synclinal basin of *Hamilton strata* with a narrow compressed trough between the main synclinal and the final rise eastward over the Blacklog mountain anticlinal. These troughs on the eastern side merge successively into the main synclinal southward, and make a number of parallel ranges of the *Marcellus ore*. Five of them are described in Report F, numbered from east to west. The sixth, along Chestnut ridge on the west side of the main synclinal has already been noticed (from Mt. Union to Three Springs).

The first ridge of Oriskany next Blacklog mountain is called Sandy ridge; two little troughs lie between it and the Royer ridge anticlinal.*

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* The Oriskany in Sandy ridge dips 80° N. W. The Royerridge southeast dip is 29°; its northwest dip 19°. In Saddleback ridge (next north of Royer ridge) the Hamilton sandstone dips N. W. only 10° or 12°, and Aughwick creek flows at its western foot. In Chestnut ridge, at the foot of Jack's mountain, the *Oriskany* rises from the northwest side of the basin. This structure produces at Orbisonia three outcrops of the *Marcellus ore* (see Orbisonia section No. I, F, 160).

But the subordinate troughs or wrinkles in the great basin (or Lewistown synclinal) undergo frequent changes along their courses. For example, only a mile and a half northeast from Orbisonia, section No. 2 shows the Royerridge anticlinal bringing the No. VI limestones to the surface between two outcrops or Oriskany dipping 33° N. W. and 75° S. E.; and the little trough between Royer ridge and Sandy ridge subdivided into two, each of which has two outcrops of the Marcellus ore bed meeting underground at depths of 100′ and 250′. A fifth outcrop runs along the northwest slope of Royer ridge; and a sixth, along the southeast slope of Chestnut ridge, on the Jack's mountain or western side of the valley, carrying the Logan farm ore bank; the Hicks ore bank; and the Stewart ore bank (5 miles from Orbisonia, (F 116).—Along Royer's ridge and Sandy ridge twenty different openings on the Marcellus ore are described (F).

The Marcellus ore bed on the southeast side of the valley along the Orbisonia outcrop, has been extensively opened in Royer's ridge and Sandy ridge; and among the openings on this bed are others on pots of ore in the Corniferous lime shales under it, and in the Oriskany still lower. Drift No. 7 of the Orbisonia map in Report F was in carbonate. In the old Bedford pit (1780?) much lump ore was mined, the wash ore being rejected, the bed folded and contorted.

In the Orbisona slope 4000 tons were mined between 1841 and 1846 from the bed 5′ thick and in one place 14′. The slope sunk in 1872 found at 70′ mixed carbonate and semi-carbonate with carbonaceous clay 3′ thick. Average analysis: Iron 42.200; sulphur 0.122; phosphorus 0.130; carbonate lime 0.990; carbonate magnesia 0.756; insoluble 19.740. A specimen of

The *Marcellus ore bed* in the Aughwick valley may be described as a series of layers of bluish gray or lead colored carbonate of iron, either massive and breaking into square pieces, or laminated and slaty, separated by thin partings of slate. Towards the surface outcrop the bed has been broken into lumps each with a kernel of undecomposed, unchanged, carbonate ore, and a shell of brown hematite. The kernel however is loose inside the shell, the intervening space being usually filled with a dust of clay when dry, and a sticky clay when wet. When roasted the whole lump becomes of a reddish brown color, and strongly magnetic.

At the outcrop the whole bed is often changed to brown hematite, but retaining a large percentage of *silica*, and the usual per centage of *water*, as in the following analysis of a specimen from the old Fleck open cut: Sesq. iron, 61.142; sesq. manganese, 0.195; alumina, 1.065; no lime; magnesia, 0.198; sulp. acid, 0.182; phosp. acid, 0.343; water, 10.395; carbon, 0.390; silica, 13.435; undetermined elements, 1.755=100 (A. S. McCreath).

In three *Fleck specimens* the iron amounted to 51.7, 46.5, 49.8; manganese, 0.136; sulphur, 0.062, 0.073, and a mere

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compact carbonate with seams of brown oxide yielded: Iron 33.700; sulphur 0.533; phosphorus 0.045; insoluble 18.520.

At the old Jordan bank large open cuts show the bed varying from 1′ to 4′ in bunches; ore good.

At the Pierce bank the bed is irregular, good brown hematite 1′ to 4′ thick.

In the fourth range, general southeast dip, open cuts show brown hematite in a thin bed turning soon to carbonate at water level.

In the fifth range, northwest dip, a drift at water level struck a little carbonate mixed with carbonaceous clay; brown hematite being at the surface 30′ higher. In the Rockhill slope (80′ deep) the bed from 1′ to 3′ thick is brown hematite for from 35′ to 50′ down; changes then to carbonate and finally to carbonaceous clay. A cross-cut and long gangway found 4′ of good ore, analysing: Iron 51.700; sulphur 0.023; phosphorus 0.068; insoluble 10.490; dark brown hematite, very hard, compact containing much ochreous iron.

At the Royer and Dewees shaft (No. 17 on the map) 75′ deep, only brown hematite and no carbonate fills the bed, 3′ to 5′ thick.

On range six, general southeast dip, Royer and Dewees tunnel through Marcellus shale struck the Marcellus ore bed only 1′ thick, containing brown hematite, and gangways finding the bed no better were abandoned.

trace ; phosphorus, 0.058, 0.133, 0.150 ; insoluble residue, 9.320, 17.120, 13.435.

At *Douglas bank* the iron was 47.3 ; at Hicks bank, 47.5. (Report M, p. 67).

At *McCarthy's bank* at Saltillo (a complete analysis was made by Mr. McCreath. The ore yielded : Protox. iron, 25.814 ; sesquix. iron, 27.000 ; bisulphide iron, 0.429 ; sesq. mang., 0.289 ; *oxide of cobalt*, 0.580 ; alumina, 2.002; lime, 1.143 ; magnesia, 0.832 ; sulph. acid, 0.502 ; phosph. acid, 0.137 ; *carbonic acid*, 15.938 ; carbonaceous matter, 2.681 ; water, 6.460 ; insoluble residue, 16.211=total, 99.918 ; representing *iron*, 39.100 ; manganese, 0.201 ; sulphur, 0.430 ; phosphorus, 0.060. The amount of carbonic acid shows that the bed has been here only partially changed. The carbonaceous matter allies it to the *Marcellus black shale* formation, as much as the residual lime and magnesia ally it to the underlying *Corniferous limestone* formation (F, 238).

Marcellus ore at Orbisona.

In the measured section through Orbisonia, the *Marcellus ore bed* is called 4′ to 7′ thick, *underlying* 750′ (?) of *Marcellus black shales*, and *overlying* (*not limestone*, which seems absent) but *shale*, 155′, down to the *Oriskany sandstone* which is 150′ thick more or less (see F, p. 132, and cross section facing p. 160).

Southwest from Orbisonia, 3 miles, shafts found the bed with 2′ to 4′ of ore, on a high dip, proving that it runs on in good condition 3 miles further to Meadow gap. The outcrop then is concealed beneath the flats of Aughwick creek. Beyond this, southwest, it appears on the road at Stamback's barn, 18″ thick, five miles from Fort Littleton. From this to Fort Littleton both the Marcellus and the Corniferous shale ore exhibit themselves at the surface.

In Fulton county the horizon seems to be unproductive. Ahl's prospecting pits on the road leading to Nine Mile Run gap from Little Scrub ridge in Dublin township (T2, 305) are not on the true Marcellus ore horizon but are on an outcrop of the drab shales 400′ higher in the measures.

Marcellus ore in the Huntingdon valley.

The Marcellus ore outcrop of the Aughwick valley, curving around the south end of Jack's mountain from Three Springs to Saltillo, past the Hudson bank, and Black's limekilns, to the *McGrath bank* on the south side of Lick creek, enters Hare valley and runs north to the Juniata river at Mapleton, with a straight outcrop and a steep west dip toward Sideling hill. At the McGrath bank the bed is from 3′ to 4′ thick, mostly carbonate however, shaly, with much clay (F2, 32). To the south of the bank the bed seems very silicious, to the north of the bank all the way to Mapleton no openings have been made upon it and its condition is unknown. It no doubt continues as a regular member of the series, but the conditions of drainage are unfavorable for its change to brown hematite and it can hardly be expected to possess any future mining value.

From Mapleton north to Mill creek the Juniata river conceals the outcrop for 3 miles; and up Mill creek northward for 10 miles to the head of the Huntingdon valley in Barre township nothing is known of the outcrop except that it runs at the west foot of the Oriskany ridge with very steep west dips.

Turning west at Conpropst mill, it takes the other side of the valley, and runs back southwest through Oneida township past Warm Springs on the west side of Standing Stone creek, to the upper end of the city of Huntingdon on the Juniata. The prevailing dip along the outcrop is 10° or 15° southeast. The valley at the foot of Warrior's ridge is excavated in the Marcellus shale 350′ thick; at the base of which lie several layers of hard, gray, greenish, Corniferous limestone; under these another formation of Marcellus black slate; under which comes another series of limestone beds like the first, but with partings of black slate, the whole being fossiliferous and measuring nearly 700′. Dark shales and clay with iron ore 20′ thick then brings us down to the upper face of the Oriskany sandstone, rising westward slowly to the crest of Warrior's ridge. The lower limestone is seen in the bluffs at West Huntingdon;

and on the opposite south bank of the river Prof. White made the following section (T3, 114.):

Marcellus black slate, bottom bed,	—
Limestone and lime shale, bluish, gray, impure,	12′
Black slates,	40′
Limestone, bluish gray and greenish gray,	10′
Dark shales and other beds concealed,	20′
Oriskany sandstone,	—

There is evidently no Marcellus iron bed over the limestone north of the Juniata river; although there are a few layers of lean carbonate ore in the clay shales between the limestone and the Oriskany (T3, 258).

From Huntingdon S. S. W. through Walker, Penn, Lincoln, and Hopewell township into Bedford county, the Marcellus ore bed seems to be nowhere in place, either on top of the limestone or bottom of the black slate; the limestone outcrop making a low but distinct terrace along the bottom slope of Warrior's ridge.* It is evident that the Marcellus ore bed was never deposited in this district; and that to find its northern limit we must proceed further southwestward along the valley into Bedford county.

Marcellus ore in Bedford county.

In Bedford county an almost straight outcrop of Marcel-

* In the McConnellstown section only 100′ of Marcellus shales are visible; 550′ down to the Oriskany being concealed (T3, 198). In Penn township at Grafton the Marcellus shales with limestones near the base shows for 265′ over the Oriskany, but no ore appears. In fact the Marcellus outcrop is black slate at the base of Warrior ridge and the low terrace of Corniferous limestone without ore. In the Patterson section (T3, 183) limestone and shales 75′ thick intervene between the black slate and the Oriskany. At Brumbaugh's crossing on the railroad, appears Marcellus black slate 75′; limestone and shales, dip 25° to 30°, 75′; Oriskany sandstone 50′. Here the limestones make a low ridge and can be easily followed, but no ore appears (T3, 182). In Lincoln township, the Coffee run section (T3, 168) shows black slate, dip 40°, 300′; impure limestone and lime shales 35′; concealed beds 40′; Oriskany 60′; but no ore appears.—In Hopewell township the Marcellus outcrop valley is covered with a local sandstone drift from the Warrior ridge, concealing the outcrops; but on Shy Beaver creek there appears black slates with limestones at the bottom, dipping 42°, 350′ and then the Oriskany, but no Marcellus ore appears. In the Weaver's run section at the Bedford county line, the black slate is about 300′ thick; under it fossiliferous gray shaly limestone beds with dark shale partings 25′; then impure limestone on top of dark lime shales with a few greenish layers 55′; then the Oriskany; no Marcellus ore discoverable.

lus runs at the foot of Warrior's ridge with a steep dip to the east, from the Huntingdon county line 20 miles S. 30° W. to Everett on the Raystown branch of the Juniata; and thence onward in the same direction 20 miles further to the Maryland state line. This outcrop will be described in the next chapter, as we are now engaged only with the ore bed at the bottom of the black slates.

The erosion of the soft rocks has been so great, as well as the local drift down upon them from the Oriskany sand stone in the ridge, that exposures are few, at least such as can furnish a measurement down to the Oriskany. An exposure near Saxton a few miles south of the Huntingdon line however, reads as follows:

Dark to black shales, fissile, ...	308′
Shale and limestone, ...	68′
Interval down to the Oriskany (black shales and limestones), ...	84′*

It is certain that the Marcellus at the foot of Warrior's ridge from Everett to the Maryland line carries ore; but nothing is known with certainty as to the quantity, for all the old trial pits are of insignificant size and have become filled up. In the southwestern corner of Monroe township an extensive deposit of bog ore lies north of Chaneysville. Samples of brown hematite from Barndollar and Bachman's land 1 mile south from Everett analysed iron 53.050; sulphur 0.056; phosphorus 0.087; insoluble 7. 800.

Marcellus ore in the Bald Eagle Valley.

In Blair county, at the northwest foot of Bald Eagle mountain, between Tyrone and Huntingdon, and southward along the foot of Dunnings' mountain to Bedford, we might expect to find the *Marcellus ore bed*, for the Corniferous limestone and Caudagalli fossils show at Tyrone City. But the only place where it has been reported is at the old abandoned pits near the railway station just west of McKee's gap, southwest of Hollidaysburg. The tradition is that the ore was locked in between black slates, and con-

*Exposures elsewhere along the line show that the black shale with limestones extend down to the Oriskany (T2, p. 83).

tained so much carbon as to lose greatly in roasting, but made fairly good but rather red-short pig iron (T, 33). It is therefore here a sort of black-band iron ore. Two specimens were picked from the place and sent to the Harrisburg laboratory. No. 1, was a dark brownish black, brittle, very carbonaceous ore, got 30′ under cover; No. 2, from near the surface, among black slates, was a dark brown cellular brittle ore, with less carbonaceous matter. Their analysis showed :—Iron 38.300, 40.500; manganese 1.395,——; sulphur 0.682, 0.024; phosphorus 0.054, 0.094; insoluble 16.330, 24.060.

In Centre county, the *Marcellus black slate* outcrop, at the west foot of Bald Eagle mountain, runs up the valley of Bald Eagle creek, without any sign of ore; and the *Oriskany* formation is apparently absent; first appearing as a distinct ridge in the little hill on the railroad between Snow Shoe intersection and Milesburg, in Boggs township, and extending thence northeastward into Clinton county.* The outcrops are almost everywhere concealed beneath the local drift floor of the Bald Eagle valley proper; and it is possible that the *Marcellus iron ore* may exist in places beneath the drift; but it does not show itself where the black slates and the underlying shaly limestones make their appearance in an extensive outcrop two miles southwest of Unionville, (T4 432).

In Clinton county, Beech creek, flowing northeast to Lock Haven, covers up the outcrops of *Marcellus* with drift like the Bald Eagle creek; the *Oriskany* occasionally but slightly showing itself.

In Lycoming county, there is the same concealment all along the valley of the West Branch of the Susquehanna, and nothing is known of *Marcellus ore*.

*T4, 290. Professor Ewing, of the State College, however, reports (T4, 430) a slight exposure of Oriskany between Julian and Martha. See Chapter on the Oriskany No. VII.

CHAPTER LXXXVII.

VIII c, Hamilton Sandstone and Shale.

The multiplication of names is an evil in science. Where old names can be used, even with some inconveniences, they should be retained for the sake of the connection which they establish between regions. The Hamilton formation was subdivided in New York originally into :—

6. Moscow shales (at the top).
5. Encrinal limestone.
4. Ludlowville shales.
3. Olive shales.
2. Skeneateles shales.
1. Dark slaty fossiliferous shales ;—

but all these names have gone out of use; because the whole series is shaly, and fossiliferous, and the subdivisions were supposed to be local.

The survey of Pennsylvania however has proved the contrary, by showing a triple subdivision of the formation which maintains itself throughout the region ; and also the persistence of the Encrinal limestone.* The natural names

* The *Hamilton formation* (*Cadent shales*) from the Delaware river to Perry county, a mass of gray and olive shales (growing gradually sandy, and after passing the Schuylkill becoming a clay sandstone, and then on the Susquehanna including silicious conglomerate beds) becomes less sandy in the Tuscarora and Shade Mountains on the Middle Juniata, reassuming its normal form of shale or fine sandy mud. On the Lower Susquehanna it is 800′ thick ; in Half-Fall Mountain in Perry county between 600 and 700′ ; in White Deer Valley at the east end of Bald Eagle Mountain (blue sandy clay and limes and sandstone, with numerous fossils) 600′ to 800′ ; between Frankstown and the Lock Mountain 400′. Growing thin from Hollidaysburg southwest, it seems to be wanting on the Potomac at Cumberland ; but on the Potomac at Sideling hill it is at its maximum thickness, 1100′; and continues through Virginia diminishing to expire near the James River. In the western states it seems to be absent. (Rogers, 1858, Vol. I, 139.) Its failure in the western states ought to bring the *Genesee* and *Marcellus* together ; which may be a reason why the *Marcellus* is supposed not to exist in the west ; being, on that supposition, the lower part of the western black slate formation ; the *Genesee* the upper part.

for the three Pennsylvania divisions would be *Upper*, *Middle* and *Lower Hamilton.* But we encounter an obstacle to the use of these terms. New York geologists have given to the name *Hamilton* a much larger scope; have made it include *Genesee*, *Tully*, *Hamilton proper*, and *Marcellus.* The real *Upper Hamilton* is therefore the *Genesee* and *Tully;* the *Lower Hamilton is Marcellus.* Writers and teachers have felt this confusion of names to be in no slight degree embarrassing. Geographical names should be given to the three divisions of the *Hamilton proper.* The name *Perry formation* would be unexceptionable for the *middle sandstone division*, because in Perry county it is magnificently developed as mountainous outcrops. No such names however offer themselves for the *upper* and *lower shale divisions.* Why should not the original New York names *Moscow*, *Skeneateles*, be revived? But if so the original New York name for the *middle division*, viz. *Ludlowville*, would naturally accompany them; or be adopted in the simpler form of *Ludlow;* especially as Prof. Hall justified its adopted by reference to its coincidence in time and fossils with the famous *Ludlow formation* of England. Therefore, in Pennsylvania it is only necessary to make the *Skeneateles shale* include all beneath the *Ludlow*, and we have a feasible scheme:—

Hamilton	Upper.	*Moscow shales.*
		Encrinal limestone.
	Middle.	*Ludlow sandstone.*
	Lower.	*Skeneateles shale.*

No. VIII c, Hamilton in New York State.

The *Hamilton formation* was named from Hamilton township in Madison county, southwest of Utica in middle New York, the surface of which is entirely occupied by its broad outcrop; which however extends the length of the state, from the shore of Lake Erie to the hills near Albany; and descends the west side of the valley of the Hudson as the foot hills of the Catskill mountains, south and southwest to the Delaware river at Port Jervis, where it enters eastern Pennsylvania. From this it runs on southwest through Pike, Monroe, Carbon, Schuylkill, Lebanon and Dauphin counties to the Susquehanna river five miles above Harrisburg. Crossing the river it zigzags through Perry county and then passes southwestward through Juniata and Fulton counties into Maryland. The whole length of this continuous *outside* outcrop is between six and seven hundred miles; to which must be added in middle Pennsylvania an equal length of *inside* outcrops, along which, in parallel curves and many zigzags, the formation is brought to the surface of the country by anticlinal waves.

Its thickness in New York seems to vary between the extremes of 700′ and 300′.†

It is thicker to the east and thinner to the west; being twice as thick on Lake Cayuga as it is on lake Erie.

In eastern New York, where the *Portage*, *Genesee*, and *Tully* do not exist, and the *Hamilton* is immediately covered by the *Chemung*, it is generally composed of *fossil sandstones*, many of its strata abounding in various species of shells, together with the remains of seaweeds, and fragments of land plants. (This is Mather's description of it in the valley of the Schoharie.) It is finely exposed in the hills which enclose the Schoharie valley, to the bed of which its southerly dip gradually brings it down in Gilboa township. Its cleavage planes are here vertical, as they are in Pennsylvania on the Delaware, and show finely near North Blenheim. It makes the highland of southwestern Albany county, and overlooks the Hudson as a terrace through which the descending ravines of the Catskill plateau are cut. Its finest exposures are along the Hawnakrauzkill at Coeymans, Albany county, and on the road to Clarkesville along the table land north of it; the steep terraces offering every facility for collecting its fossils. Further south, in Greene county, it is well exhibited by the stream along the road from Catskill to the the Mountain House; and along Catskill creek between Madison and Cairo; on Potack

* Prof. Hall says its thickness on lake Cayuga etc. cannot be less than 1000.; although the undulations make it hard to measure. Each of its subdivisions thins toward Lake Erie where its thickness is less than half that amount; but only 100′ of it is actually visible. The *Moscow* shale is 15′ (on Lake Cayuga 50′ to 60′); the *Ludlowville* is scarcely 1′ thick on Lake Erie (1843, p. 194).

creek; in the Greenville ravines; and through New Baltimore and Coxsackie townships. Further south they are well exposed by the Plattekill, Saghkill, Esopus, Mombockerkill, Rondout, Goodbeerkill, and finally, the Delaware river.*

In middle New York, Vanuxem says that its strata of fine shale, coarse shale, and sandstone are not arranged in any definite order; although the sandstone beds are more common in the middle of the series. The fine grained shale is often a bluish or blackish slate splitting into leaves. Its coarser shales are often calcareous; usually dark blue gray inside, but olive or brown after long exposure to the weather, owing to the oxidation of a percentage of manganese which they hold; and do not lie in regular layers, but after long weathering show short irregular curved partings. The few real sandstone strata are separated by shales, and pass into shale; lying in irregular layers of no great extent; sometimes calcareous; and colored olive, greenish, yellowish, and brown of various shades. Only those which are made up chiefly of sand cemented with lime-mud furnish building stone.†

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* Unfortunately, Mather did not report the *Chemung, Ithaca, Hamilton and Marcellus* separately, but only in the gross, as the *Erie division;* so that we can only know the *Hamilton* from Vanuxem's and Hall's studies of its outcrops between the Schoharie and Lake Erie.

† In Otsego county the Hamilton outcrop is 15 miles wide, i. e. from the hill tops at Cherry valley the whole length of Middlefield township to its southern line. Otsego lake is excavated in it to its southern end; also Schuyler's lake. The Unadilla river flows south across it for eighteen miles. It makes one-half of the area of Madison county. On the highland west of the Chenango river it narrows to six or seven miles at Casenova; and widens again in Onondaga and Cayuga counties, making the bluff sides of the lakes. It extends up Cuyuga lake to within 3 miles of Ludlowville; its southern limit being represented by the thin outcrop of the *Tully limestone.* Here its extremely gentle dip towards Pennsylvania can be studied for many miles, and calculated with great precision; being at the rate of between $\frac{1}{3}^\circ$ and $\frac{1}{2}^\circ$, or say 40′ to the mile; but with broad gentle undulations running east and west. Three of these undulations appear along the shore-bluffs of Seneca lake. The great breadth of the New York outcrop is thus explained; for, upon a level plain, a dip of $\frac{1}{2}^\circ$ will spread a thickness of 500 feet over a breadth of 10 miles. (On the Delaware 1000′ dipping say 15° it has an outcrop of two-thirds of a mile only; and on the Susquehanna 2000′, dipping 45°, an outcrop of less than half a mile.)—From Seneca lake to Lake Erie the outcrop runs, with a width varying from 5 to 8 miles, through Seneca, Ontario,

In western New York, Hall says that the whole formation may be considered one of dull olive or bluish gray limy-shales ; weathering light gray or ash color, but some layers brownish ; at a few exposures only darker or even black, with a tendency to slaty structure; cleavage (bedding) generally irregular and *oblique ;* weathered surface however exposing a general tendency to slaty (cross) cleavage,*

Its changful character.

The most striking feature of the New York outcrop is its change from east to west in three respects:—(1) from thick to thin—(2) from sandstone to shale—(3) from lamellibranch to brachiopod life ; and it is evident, as Prof. Hall showed nearly fifty years ago, that these three items of variation are in harmony with one another, or depend on each other. That is, the formation was deposited more thinly westward because the finer mud only floated far in that direction before subsiding to the bottom. And as during the process two different kinds of sea bottom were produced, so of two different families of shell fish, one selected the eastern sandy, the other the western muddy sea bottom as its most congenial habitation. "In the eastern part of the state, *Avicula* and *Cypricardia* with *Nucula* etc. prevail in immense numbers ; while at the extreme western margin these genera, though in precisely the same position, are of the rarest occurrence, while numerous forms of *Delthyris* [*Spirifera*] and *Atrypa* abound."†

Livingston, Genesee and Erie counties. On Seneca lake it reaches nearly to the village of Ovid, the most southerly point in its course to Lake Erie. West of Seneca lake it bears north to Canandaigua, whence its bottom beds run along the north township lines of Bloomfield and Lima. It crosses the Genesee river between Caledonia on the north and Genesee on the south, and continues to Buffalo.

* Evidently, he adds, deposited in an age of general tranquility as fine mud carried far and wide by gentle ocean currents, feeding multitudes of living creatures, especially shell-fish ; the currents setting from the east or southeast westward, because the deposits are sandier and coarser in eastern New York. But judging from their extreme coarseness in Pennsylvania the currents set northward.

† Hall, 1843, p. 186. In a foot note he expresses a geological principle, then new, but now commonplace; and because so commonplace overlooked too

The Hamilton formation in New York abounds in fossil shells, corals, trilobites and seaweeds; and a few land plants have been found in it, which no doubt were floated into the sea by some far away river current. It is in fact the most fossiliferous formation in New York; many of its species being peculiar to it, coming into existence apparently while its deposits were being made, and not continuing to exist afterwards at least in this part of the ancient sea.

At first there lived an abundance of *Orthis*, *Atrypa* and *Strophomena*, with some *spiral univalves*. Then followed shell banks of *Avicula*, *Cypricardia*, *Nucula*, and other similar forms—with a smaller number of *Orthis*, *Delthyris*, (*Spirifer*), etc. After this an age of *Delthyris*, *Strophomena* and *Atrypa* set in; the previously living shell fish being almost entirely extirpated. Corals of various kinds are found, and the stems of stone lilies, disjointed and scattered through the mass, or spread evenly in solid thin layers. And as this third age went on, many of its species perished, and were replaced by or changed into others of the same genera whose remains fill the uppermost layers of the formation.*

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often:—"The lithological character of rocks therefore is an element to be taken into consideration when we undertake to identify strata by their contained fossils." He illustrates the principle by reference to the sandy "haddock ground" and stony and rocky "cod ground" of the Atlantic bay.—On the other hand, the contrast in the prevailing fossils of *Hamilton* age with those of *Marcellus* and *Corniferous* age is as great as that of the rock strata which contain them. "We sometimes indeed meet with a [Hamilton] species which occurs in the [Corniferous] limestone below, but" rarely. "Some of the more abundant *corals* are identical, but the great number of new forms renders them of less importance, and in all instances they are too few in number to produce any doubt or difficulty in identification of strata. Shells both of Branchiopoda and Dimyaira have immensely increased, and in many single localities from twenty to fifty species of fossils may be obtained. * * * Their great number and exquisite perfection * * * will delight the mind of every lover of nature. Here it seems, that instead of extracting them from the solid rock, we are culling them from the dried ocean mud, which a late retiring sea has left above its reach, so much do these soft shales resemble the mud deposits in the bays and creeks along the sea shore" (p. 195, 196).

* It is an interesting fact that the *Hamilton upper* (*Moscow*) *shales* closely resemble the *Niagara* shales; and are even more prolific in fossil remains; corals and shells of similar genera (but entirely different species) abounding in both; and trilobites of the same and also of different genera (but none of the same species) also.

In western New York there is visible a westward thinning of the subdivisions of the formation so great that on Lake Erie they sum up less than half of the total thickness on Seneca lake. But many of the fossil species maintain their respective horizons, or places in the series.* Some of them grew in greater numbers; others, like *Cypricardia*, *Avicula*, *Nucula*, *Bellerophon* and a few more, grew in less numbers on account of the deficiency of the sandy lime-shale element.

The Hamilton formation is in fact a series of separate subordinate formations. And we may find a key to their series or vertical arrangement in a horizon of *conchiferous mollusca* which lived abundantly in eastern New York in a thick deposit of *sandy shale* (also in great numbers in middle New York) which can be recognized by its extra sandiness, and by the same group of fossils on Lake Erie.

But at the same time, and in spite of what has just been said, the sandy central portion of the *Hamilton formation as a whole* can hardly be distinguished on Lake Erie from the upper and lower portions, which in eastern New York (and still more so, in middle Pennsylvania) are shaly, in strong contrast to the sandy middle portion. Moreover the thin *black slate* beds so common on the little lakes are wanting on lake Erie, and their peculiar fossils (an *Orbicula*, *Atrypa congregata*, Conrad, and some others) are also wanting.†

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* Stratum *a*, for instance, in Hall's Section Plate 5, holding *Cypricardia*, *Turbo*, *Bellerophon and Orthoceras, and almost nothing else*, represents on Lake Erie a similar but thicker set of beds which, on Lakes Seneca and Cayuga, underly the uppermost beds of the *Ludlowville shale* (*S. mucronata, etc.*)

† Hall remarks that although the Lake Erie section abound in fossils there is a manifest decrease in the number of species; many common eastern species are missing, and scarcely any new ones appear. But the abundance of individuals compensates for the fewness of species.—On Lake Erie, moreover, the lower sub-divisions of the Hamilton (below stratum *a* of Hall's section) are nearly non-fossilferous; none of the peculiar forms found in middle New York are to be seen. The three upper subdivisions are the interesting ones.

VIII c. New York subdivisions described.

The Hamilton formation being completely cut through by Seneca and Cayuga lakes four outcrops offer themselves to examination where the formation is well developed. Its subdivisions, as described by Prof. James Hall in his Report of 1843, p. 187, may be indicated thus:—

1. *Moscow shale** (at the top); well defined (between the *Tully Encrinal limestones*) and persistent; † greyish blue; scarcely laminated; breaks irregularly; rarely slaty; slightly calcareous; full of fossils, many of which are unlike those below, and most of them are not found above. It is well seen at Ludlowville, east shore of Cayuga lake; at Lodi on Seneca lake; at the outlet of Crooked lake, well exposed (with the *Tully*) and yielding great numbers of the finest fossils. ‡ It is finely exposed along the deep gorge of the *Genesee river* and in its natural ravines, especially at Horsford's on Beard's creek, Livingstone county, where more than *fifty species* of fossils can be collected, many of which do not occur in the middle and lower Hamilton. § Its fossil corals are its chief attraction to the collector. ‖

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* Named from Moscow, Livingston county, where it is beautifully exhibited at Horsford's on Beard's creek.

† But it diminishes westward from 60′ at Lake Cayuga to 15′ at Lake Erie.

‡ See Hall's picture of the curious sugar loaf bluff, between the lake outlet on the right and canal on the left, p. 184.

§ Here it is a pure lime mud rock, bluish, weathering ash colored; pyritous, and falling to pieces; pyrites often replacing the fossils; not capped by *Tully*, but by *Genesee*.—The *Moscow* can be seen near the base of the falls on Fall Brook, south of Geneseo; and the Conesus outlet.

‖ The *Moscow shales* are more calcareous than the *Ludlowville shales*, darker and finer also, but some of its fossils are common to both (in Vanuxem's district) and some are more abundant (such as *Orthis resupina*, *Phacops bufo*. and *Dalmanites*), but not so to the eastward of Lake Cayuga. *Cypricarditis recurva* occurs in it only on the lake; near W. Hamilton it occurs lower down in the sandstone layers. Such facts, with the disappearance of the *Encrinal limestone* eastward, induced the N. Y. geologists to give up the distinction between *Moscow* and *Ludlow* subdivisions. —In Otsego co., at Cherry Valley Falls the coarse shales are full of *Spiriferidæ*, *Conularia*, *Dalmanites*. Higher up in the sandy layers are many *Pterinea flabella*.—On both sides of Otsego lake the *Moscow shale* abounds in the *Ridged Posidonia*, *Spirifera mucronata*, *Athyris spiriferoides*, *Keeled Atrypa*, *Dalmanites*, etc., etc.—Three miles from Burlington, on

2. *Encrinal limestone* (under *Moscow shale*); persistent and continuous to lake Erie; a thin bed of impure limestone, full of *encrinal stems;* sometimes however a compact shale *held together* by *encrinal columns of great size and length.* Other fossils (shells) are also numerous.—In Darien, Genesee county, it is a compact layer (3′ thick), its upper part strongly stained with decomposing iron pyrites. Near Alden, further west, it is quarried; full of *crinoidal columns; Spirifers; Pleurotomaria* (whorled shells); and the trilobite *Phacops* (*Calymene*) *bufo.* Here and elsewhere it seems to be "a common depository of many or all the species of the (*Ludlowville*) shale below, with several others which are peculiar to itself."*

3. *Ludlowville* † *shales* (under *Encrinal limestone*); upper layers a soft bluish-gray, somewhat calcareous and fissile, with its own association of fossils; lower layers sandy and so compact as to fall in large masses, which resist the weather for a long time; passing downward by in-

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the Cooperstown road, the oldest land plant was found. Mather found a considerable abundance of them on the road from Summit to Hinsdale. Another was got in a quarry near the forks of the Unadilla, see Fig. 38, in Vanuxem's Rt. 1842, p. 157.

* Prof. Hall adds as an explanation: "It was of course produced during a cessation of the mud deposit; and the forms living on the bed of the latter would consequently be inclosed in this deposition, with others produced on the calcareous bottom, some of which were different (1843, p. 190).—Vanuxem describes the *Encrinal limestone* on Cayuga lake (1842, p. 155) as a rather tough, brownish, impure limestone only 3 or 4 feet thick, containing numerous encrinal discs and shells. He adds that it was not certainly recognized east of Cayuga lake; and that the ledge of *encrinal limestone* south of Borodina is probably *Tully limestone*, under the *Genesee.* This shows how easy it would be to mistake the outcrops. A very good exhibition of the way in which the encrinal joints and parts of stems lie in the rock mixed with fragments of corals and shells, is made in Fig. 83, page 204, of Hall's report of 1843; and of the way that the encrini were covered with bryozoa after their death, in Fig. 83. 2, representing a fragment of a large species so covered, with its five stared internal canal filled with crystallized silica. Even larger columns than this one are often found; they are usually furnished with branches; and when the branches are broken off the columns look like knotted or knobbed sticks.

† By a happy coincidence the two higher, this and the next lower (four) subdivisions, well shown at Ludlowville on Cayuga lake, represent in America the *Ludlowformation* on the Welsh border (Hall, 1843).

sensible gradations into the underlying *Olive shale.** — Well seen, north of the turnpike from Geneva to Canandaigua in several ravines; full of *Spirifera mucronata*, *Athyris spiriferoides* (*Atrypa concentrica*), and one or two species of *Strophomena* (*Strophodonta*). Lower part full of *Cypricardia* and *Avicula.*—In the Genesee valley, a mile west of York, a fine exposure shows the shale crowded with *different species of cup-corals* (*Cyathophylla*) *Favosites* and other kinds of coral, some *trilobites* and *shells.* †

4. *Olive concretionary shales* (under the *Ludlowville shale* on both lakes); often a bluish fissile shale; marked by lime-balls, or concretions; ‡ upper layers olive, very fissile, stained with manganese; a few cup-corals (*Cyathophylla*), and some other fossils.—This olive shale thins away west of the Genesee river, and almost entirely disappears before reaching Lake Erie.

5. *Skeneateles lime shale;* blue (under the olive); often a compact *bastard limestone;* thin; pretty persistent; parts the olive shale and dark slate subdivisions on both lakes; on Flint creek; and as far west as the Genesee river. It is however a tolerably pure *limestone* in York

* This sandy division is seen gradually thinning away toward Lake Erie. Along Cayuga creek it has almost entirely disappeared. On Lake Erie Hall says it is *only one foot thick.*

† At the center of Darien township, Genesee county, a good exposure shows the shale abounding with *Atrypa reticularis* (*affinis*); *Athyris spiriferoides* (*Atrypa concentrica*), *Spirifer mucronata*, and other similar shells; and corals (*Cyathophylla*, *Favosites*, *Strombodes*, etc.).

‡ Concretions (*septaria*) round, oblong, or fantastically shaped, are common throughout the whole Hamilton formation. The particles of carbonate of lime have been attracted by and to and condensed around some solid substance in the mud, a shell, or fragment of coral, or previously crystallized knot of iron pyrites. A concretion will hold several fossils, and have others stuck in its surface. Most of them however have no fossils, and seem to have conglobed about a mere point, they are so round; and some, particularly in the lower part of the shale mass, are small, round, flattened or oblong, with a fine hole passing through their center, like those of the recent Champlain clay. Some have a hollow center, lined with crystals, or partly filled with petroleum (fluid bitumen). Some show that they have expanded and cracked and been recemented along the cracks with calc-spar, or merely with clay. People think they are petrified tortoises. (See wood cut of one in Hall, 1843, p. 193.)

township west of the river. Further west on Cayuga creek, and Lake Erie it almost entirely disappears.*

6. *Dark shale* (bottom of *Hamilton*, passing down insensibly into *Marcellus black shale*); slaty; not very abundant in fossils; seen in Varick and Fayette, Seneca county; Flint creek and Mud creek, Ontario county, as described by Vanuxem in foot note above.

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* Vanuxem says (1842, p. 155) that on Lake Cayuga the first rock seen south of Springport is taken as the dividing plane between Marcellus and Hamilton, a dark slaty shale holding many specimens (mostly small) of *Ambocœlia* (Orthis) *umbonata* and *Leiorhynchus* (Orthis) *limitaris*. The *Ambocœlia* occurs by myriads in Cayuga county at this horizon; but not so in the Schoharie district.—In the interval between Levana and Aurora come the second (ascending subdivision) the *Skeneateles shales*, less fissile, more calcareous, a greater number of kinds and individual shells, *Spirifera mucronata*, *Phacops* (*Calymene*) *bufo*, *Strophomena linearis*, *Ambocœlia umbonate*, etc.—In the bluffs south of Aurora lie the *Olive* and *Ludlowville shales*, in which the most common fossil is *Athyris spiriferoides* (*Atrypa concentrica*) mixed with species of the *Skeneateles shales*.—Then at Ludlowville comes down the *Encrinal limestone*, and then the *Moscow shales*.

CHAPTER LXXXVIII.

VIII c, Hamilton in Pennsylvania.

Looking at the Geological Map of the State it will be seen that the Hamilton formation comes to the present surface only in one long line from southern Pike county to Perry county, in two long lines from Luzerne to Union county, and in many long lines and zigzags in all the counties of middle Pennsylvania between the Susquehanna and the Maryland line. From all southeastern Pennsylvania it has been swept away. In all the northeastern, northern and western counties back of the Allegheny mountain it is so deeply buried that only a few of the very deepest oil borings have touched it, and only three have gone through it. In fact we know nothing about it under all the country between the Mohawk and Delaware at the east, and between Buffalo and Altoona at the west. It does not come up to water level in the gaps of the Conemaugh and Youghiogheny in the southwest.

In the great gorge of the Delaware, which resembles the meandering trench of a fortified camp, or beleagured city of the middle ages, the top of the *Genesee* makes its first appearance, on its southward rise of 11° at the 90th mile post of the Erie railroad.*

The *Hamilton* begins to show its gray and more sandy top layers a quarter of mile south of the 90th mile post, rising at the rate of 10° to 15° (S. E.) higher and higher in the gorge, until they reach the table land above. Two precipices, 600′ high, face each other, rising from the New York and Pennsylvania banks, down upon which perpetually fall millions of splintery fragments, making taluses which lean against the cliffs, and ready to slide into the rapid river

* Dark sandy slates, 200′ thick, holding *Spirifera mucronata*, *Athyris spiriferoides*, *Tropidoleptus carinatus* (?).

when its floods are swollen, and to be ground to mud and carried to the sea.*

It is a formation of fine gray sandy mud, 1375′ thick;† mostly thin bedded; containing no such coarse and massive indurated sandstone strata as make mountain ridges of this formation west of the Susquehanna river.‡ It is a compact sandy and slightly calcareous *slate formation* traversed by cross cleavage planes, at an angle of 60° (S. E.), which aid in producing bare and lofty precipices.§ Its fallen fragments are long thin angular splinters, like broken slate pencils, which make without further preparation the best possible "gravel" for the repair of roads.

Fissures in the mass are lined with crystals of quartz; their narrowness and irregular shapes show that they were planes of weakness along which slight earthquake movements once took place. Traces of *lead*, *zinc* and *copper* salts have been deposited; and *manganese oxide* ‖ (or black wad) is sometimes seen; but none of these nor any other mineral exists in paying quantities in this formation.

Fossils are not numerous; and those which can be found

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*A study of the cascades described further on in the text shows that they are in recently constructed rock cuts, the ancient water channels having been obstructed by drift left behind on the retreat of the northern ice. Had the old channel of the Delaware river been thus blocked, and the present gorge been made since the ice age, Pennsylvania would now be able to boast a Hamilton cascade near Port Jervis equal in height and almost in grandeur to Niagara Falls' As it is, the river has only a *Hamilton rapids* at Sawmill Rift, where the Erie RR. crosses it, half way between Port Eddy (571 A. T.) and Port Jervis (440 A. T). The river descends in 11 miles, 131′. (N, p. 97).

†This is Prof. White's *estimate*, from an average of the dips for three miles (across the strike) from Sawmill Rift to Port Jervis. But the total concealment of the *Marcellus* in the deeply buried ancient channel helps to make the estimate untrustworthy. His estimate of the formation on Broadhead's creek above Stroudsburg in Monroe county is 1200′:—on McMichael's creek, at Broadheadsville, further west, 1100′; on the Lehigh river, in Carbon county, not quite 800′ (G6, 111).

‡Yet this is the coarsest part of the Delaware river outcrop; small pebbles may be seen scattered plentifully through a group of beds 20′ thick on the New York bank of the river about a mile above Port Jervis (G5, 111).

§The whole height is not precipitous, but broken into ranges of cliffs one above another from bottom to top, some of which are only 10′, others 50′ vertical.

‖ As at Quick's Mill run 2½ miles above Milford, where some fruitless diggings were once made to find a bed of it.

are of the larger species:—*Spirifera granulifera*, *Spirifera arrecta*, and *Grammysia bisulcata* among the shells;—*Heliophyllum halli* and other corals;—with multitudes of scattered discs of stone lily stems (*crinoids*);—but not a single *trilobite* was fonud by Prof. White anywhere along the line of outcrop through Pike and Monroe counties.*

This Hamilton outcrop is a notable feature of the topography of eastern Pennsylvania. Twenty-five miles of cliffs stand along the right bank of the Delaware from Port Jervis to Walpack Bend—a leaning wall,† built up in horizontal courses to a height of 500′, rising in places to 600′ and at Utter's Peak near Milford to 800′ above the river level at its foot—a great retaining wall to the elevated rolling country behind it, composed of *Chemung* and *Catskill* plains and terraces rising higher and higher to the *Pocono* mountain plateau.‡

The mouths of many ravines break the monotony of the *Hamilton escarpment*. From some of these deep, dark glens issue small brooks after a short precipitous descent from the upland. From others pour larger streams like the Sawkill, Rameyskill,§ Dingman's creek, the Little Bushkill, and Middle Bushkill (Saw creek) all in Pike county. These head in and keep at their average annual level little lakes ‖ which lie scattered over the drift-covered upland. a

* *Athyris spiriferoides* was also found (with *S. granulifera*, *G. bisulcata*, and *crinoidal stems*, at Marshall's falls in Monroe county (G6, 255).—On Broadhead's creek, *Spirifera*, *Tropidoleptus*, *Avicula* and *crinoids* abound in the upper beds (G6, 271).

† The cleavage planes, which pass through the whole formation from top to bottom with a universal dip of 60° or 70° (S. S. E.) are probably responsible for the precipitous aspect of this escarpment. The slate-pencil character of the *dêbris* which falls from its weathering cliffs shows the internal lamination of the beds.

‡ In previous chapters it has been said that the lowest 200′ or 300′ of this wall is made by the outcrop of the underlying Marcellus formation; and that the superb carriage drive of the Medford turnpike from Stroudsburg passes along beneath the cliffs and above the river flats.

§ It has become fashionable to call this the Raymondskill. *Kill* is the Dutch word for a little river, and was brought to the valley of the Delaware, from the valley of the Hudson. *Schuylkill* is a relic of the old Dutch names in southern Pennsylvania.

‖ See the Geological map of Pike and Monroe, and also the Glacial map, in report G6. These ponds will be described in future chapters on the *Catskill* formation, and on the *Glacial Drift*.

few miles distant from the river.* Further west, in Monroe county, issue the Big Bushkill, Marshall creek and Broadhead's creek in like manner from the escarpment as it runs on back of Stroudsburg; and so on in a long series to the Lehigh river in Carbon county.

The most beautiful *cascades* of Pennsylvania make perpetual music in these recesses of the Hamilton wall. Those of the Sawkill at Milford and of the Ramyskill, three miles southwest of Milford have been made famous by tourists and artists. Almost inaccessible for many years, they were only seen by adventurous lovers of the rare in natural scenery, who could clamber down into their abysses from ledge to ledge and from tree to tree, unable to find a point of open view, and only peeping at them through the dense underwood. †

The Sawkill falls.

The *Sawkill*, descending from the upland of *Chemung strata* to the Milford-Owega turnpike bridge, flows on in a channel which it has excavated through Glacial drift, for 400 yards; then for another 400 yards through a deep and narrow trench which it has (since the Ice age) cut through the *Genesee blackslate* formation ‡ and then makes its First fall, a *double cascade*, of 20′, over the *Tully limestone*. The gorge here widens and the stream begins a gradual descent over a gently sloping platform across the thin edges of the *Hamilton* top slates; then makes its Second plunge and principal cascade of 60′, into a huge circular pool; and passes on through a channel only 2½′ wide, with a fall of 15′ into a chasm (2′ to 10′ wide) between overhanging walls of rock strata 75′ high.

For the next half mile the Sawkill cuts a channel 10′ deep

* Sawkill pond (6 miles), 800′ above river level; Log Tavern ponds (6), 900′; Silver lake (6), 900′; Mud pond (8), 900′; etc.

† They were among the earliest delights of my geological career. I well remember how impossible of near approach they were in 1839, how sedulously they seemed to conceal themselves from intrusion, how wierdly beautiful they were, and how few persons even in Philadelphia knew of their existence. But Franklin Peale knew them well.

‡ This cut is 110′ deep (at the head of the upper falls), 50′ wide at top, 10′ to 15′ wide at bottom

and only 5′ wide at the top (so that one can spring across it anywhere safely even when the flood is swollen) through successive bluish gray sandy slate rock strata rising down stream (S. S. E.) at the rate of 16°. Then comes its Third cascade of 50′ (the Bridal Veil) broken into a mass of foaming water by a series of rock ledges, very fair to look at from below.

From the top of the Second cascade (660′ A. T.) to the foot of the Third cascade (510′ A. T.) the vertical descent has now been 150′. The creek has still to descend 130′ to reach the river (380′ A. T.) a mile and a quarter distant.

A quarter of a mile below the Third fall, just above a road-bridge, massive rock beds rise at 15° (S. S. E.) ; and just below the bridge, grey coarse and rather massive but irregularly curled and twisted *Hamilton* strata rise at 12° to 14° (S. S. E.).—Further down, the stream flows through a wide vale (the original preglacial valley of the Sawkill) to opposite the main street of Milford, where it falls 18′ over a dam of dark bluish sandy *Marcellus slate*, rising at 13° (S. S. E.), and enters a gorge (30′ wide between vertical walls of slate) which becomes "the Glen", a delightful retreat for summer visitors who annually throng the place.

The last cascade is made by dark sandy *Marcellus slate* (20′) at the mill dam, a quarter of a mile from the river. (G6,198).

The Ramyskill falls.

The *Ramyskill cascade* is more concentrated. and its gorge even more wildly picturesque. From the road bridge (675′ A. T.).* the stream descends rapidly with small cascades for 400 yards to the top of the falls (595′ A. T.); then, in two leaps of 80′ and 45′ it plunges into the upper end of a narrow sharply winding dark cool glen, whose forest

*Some distance above this bridge at Lareaux's school house the Ramyskill, like the Sawkill, cuts it way through the Glacial Drift which stopped up the older channel (excavated in the *Genesee*) along which the Ramyskill once flowed (northeast) into the old channel of the Sawkill. Both streams were thus compelled to excavate their present gorges; and the high cascades show that they have not had time enough to perform more than a part of their allotted task (White in Report G6, 202).

covered walls, 200′ high, admit no sunshine at any hour of the day. The rocks are of hard blue gray *Hamilton sandstone*, rising 15° to 17° (S. S. E.). From the foot of the falls (470′ A. T.) the remaining mile of distance the stream has cut a cañon through the *Marcellus* to the river at 370′ A. T.

Adams creek, 6 miles from Milford, descends through the *Hamilton* by numerous cascades, each from 10′ to 20′ in height.

Dingman's falls.

Dingman's falls, 8 miles from Milford, are 2 miles back from the river; the top of the falls (645′ A. T.) a shelf of hard bluish gray *Hamilton sandstone* rising 12° (S. S. E.); height of falls 130′, in three cascades of 10′, 20′ and 100′; bottom of falls (515′ A. T.) rocks rising 10° (S. S. E.); level of creek at the river road 385′ A. T.

Hornbeck's creek, 11 miles from Milford, has its high Hamilton cascades.

Schoonover's run near its head, makes a high cascade over the *Hamilton* upper beds.

The Bushkill falls.

The *Bushkill falls*, 16 miles from Milford, on Little Bushkill creek, begin about three quarters of a mile below the bridge at R. M. Cook's. At first the stream cuts a deep, narrow trench through the black *Genesee slates* with a gradual descent of 50′ of gentle rapids (to 700′ A. T.). Here, over the top layers of *Hamilton* (and *Tully limestone*) it plunges 75′ into a deep pool, surrounded by an amphitheatre of vertical cliffs, passing out of which by a narrow chasm it makes another cascade of 50′ to the bottom of a deep dark wooded cañon, wild and grand, and much resorted to from Stroudsburg and the hotels at the Delaware Water Gap. Level of creek at its mouth 350′ A. T.*

*The Middle Bushkill (Saw creek) has only a small cascade (15′) in its cut through the Hamilton. The Big Bushkill (western branch) has none at all. The only explanation at hand for this difference seems to be the as yet undiscovered existence of an old channel by which the Little Bushkill flowed southwest, in *Genesee*, into the Middle Bushkill valley. When the northern glacier filled this up with moraine matter the creek began its present straight southeast rock cut to the Big Bushkill near the river (G6, 213).

Saw Creek falls section.

The *Saw creek cascade* is only 15′ high, at the very top of the *Hamilton formation*, 1½ miles up the creek from its mouth. The section here is important for establishing the relations of the *Tully limestone* to the overlying *Genesee* and underlying *Hamilton*.

Genesee	dark sandy slate, well exhibited, ...	50′
	dark sandy very hard slate (falls), ...	15′
Tully limestone	(fossil coral beds), ...	30′
Hamilton	grey coarser sandy slaty beds *dipping* 10° (N. N. W.), and making great cliffs for more than a mile on both sides of the creek.	—

The *Big Bushkill* has no *Hamilton* cascades because it has cut its channel back through *Genesee*, *Portage* and *Chemung*, so that now its high falls are over *Catskill* rocks. Its gorge is walled to a great height (800′ A. T.) with Hamilton upper very hard sandy slate, in massive looking cliffs, descending gently northward to the floor of the gorge, which, accessible to the explorer only in dry seasons, affords one of the best opportunities for a minute and systematic study of the upper *Hamilton*, *Tully*, *Genesee*, *Portage* and *Chemung formations*, as they slowly sink in regular succession under ground, to reappear along the New York State line and further north.

Marshall's falls, on Marshall's creek,* is a nearly vertical cascade, 35′ high, at the bottom of a gorge only from 5′ to 8′ wide, falling over hard sandy *Hamilton bottom slates* into a large circus of soft *Marcellus*.

Pocono creek, in Stroud township, falls 20′ in 300 yards, in a set of little cascades over blue gray sandy strata dipping 8° to 10° (N. N. W.) just below the dam of the Tanite company's works, opposite which rises a *Hamilton slate* precipice 65′ high.†

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*Just below where the township line crosses it, 23 miles S. W. of Milford. and 5 miles N. N. E. of Stroudsburg. Top of falls 550′; foot, 515′, A. T.

† Broadhead's creek flows through the *Hamilton belt* (a mile wide) the top layers of which are at water level 1¼ miles below Spragueville. The ridge of hard rocks rises to 750′ or 800′ A. T. RR. grade at Spragueville being 490′ A. T. The *Tully limestone coral beds* at the top of the *Hamilton* are seen along the Stroudsburg–Spragueville road, 400 yards south of the bridge over Broadhead's creek.

VIII c. Southern outcrop topography.

From the bend of the Delaware river at Port Jervis to the Lehigh, the Schuylkill and the Swatara, the Hamilton formation has a common character, a common aspect and topography, and a structure which repeats itself three times in the course of more than a hundred miles. Its beds are almost wholly of soft shale, with scarcely anything worth calling sandstone in them. Its softly rounded and beautifully scalloped hill-slopes, cultivated from base to summit, contrast strongly with the rugged and rocky escarpments of the formations which go and return in zigzags through the middle counties of the Juniata country. No landscape is more characteristic or strikingly beautiful than the long vistas of those bossy half-hills, arranged with such astonishing regularity as to suggest the cabinetmaker's art, when seen slantwise from any point of view on the Oriskany outcrop opposite. Innumerable rills trickle down between the short boss-like spurs into the Marcellus valley. The dips are low, usually ranging between 10° and 30°. The height of the ridge seldom exceeds 300 feet.

In Pike county there is but an exceedingly gentle north dip, sothat the escarpemnt of Hamilton rocks facing the Delaware river from Port Jervis to Walpack Bend supports a table land of Portage-Chemung stretching back to the foot of the Catskill-Pocono mountain wall; and across this table land flow in deep trenches the Sawkill, Raymeskill, Bushkill, and Marshall's creek, each tumbling in high and picturesque cascades over the nearly flat edges of the Portage sandstone.

In Monroe county, going west from Broadhead's creek the Stroudsburg anticlinal and synclinal begins to give three outcrops to the Hamilton; the innermost or northern one, dipping north more and more steeply until at Weissport on the Lehigh it plunges vertically under the mountain. The other two represent the eroded sides of a central basin, with Hamilton flanks, a flat Chemung ridge, and a high central strip of the lowest Catskill beds left in patches or long strips on its top. These are marked in red on the colored county maps.

In Schuylkill county, just at the Little Schuylkill river, the two anticlinal outcrops point together and sink at Centreville beneath Wild Cat mountain. The southern synclinal outcrop runs on past Orwigsburg to the Swatara at Pinegrove. South of it, overlooking Schuylkill Haven, is a synclinal basin, repeating the structure on the Lehigh, with two Hamilton flanking outcrops, a Chemung table ridge (Summer Hill) and a flattish Catskill crest, as shown on the colored county map. At Pinegrove the two anticlinal outcrops point together and sink westward beneath the Dauphin county Second mountain. The southern synclinal outcrop swings round to Auburn and runs on west to the Swatara Water Gap, beyond which it makes a terrace to the Blue mountain into Perry county.

VIII c. Hamilton on the main Susquehanna.

We have seen how the *Hamilton sandstone*, 800′ thick at the Kittatinny gap at Marysville, breaks up into an upper and lower massive sandstone with a middle shaly sandstone northwestward through Perry county; and grows shaly up the river at the Liverpool end of the Tuscarora mountain axis. We have now to follow this change in it northward, up the river to Georgetown, where two short anticlinals bring it to the surface in four outcrops, making two long pointed ovals.*

Approaching Georgetown from the south two great sandstone formations rise in succession at the rate of 40°, exhibiting the following section along the Northern Central railroad to the 119th mile post .—

Hamilton	*Selinsgrove upper sandstone*,†	300′
	Shales, olive brown ; lower 50′ sandy, . .	325′
	Selinsgrove lower sandstone, ‡	100′

* Fisher's ridge starting from the river below Georgetown and running east 12 miles, and Swartz's ridge starting from the river 2 miles above Georgetown and running east 9 miles, meet at the N. E. corner of Jordan township, Northumberland county. They are both made by the *Selinsgrove upper sandstone*, which sinks eastward deep beneath the anthracite region. They are high and rugged.

† This is the *Montebello upper sandstone* of Prof. Claypole in Perry county. Much of it is massive ; its beds very hard, varying in color from greenish gray to yellow. It is here 100′ thicker than at Selinsgrove, 12 miles further north (G 7, 373).

‡ This rock is typical Hamilton sandstone, grayish white with a tinge of pink, in beds from 1′ to 4′ feet thick. At the 119th mile post it makes a beautifully arched cliff 100′ high ; and, dipping north and south, makes two out-

Only a mile further up the river (at the 120th mile post, and within a mile of Georgetown) these formations rise to make Fisher's ridge, and show the following modification of the *lower sandstone* mass:—

Hamilton	*Selinsgrove upper sandstone* (*100'* visible),		—
	Olive brown shales,		300'
	Selinsgrove lower SS. gray, massive,	10'	50'
	Sandstone shaly, and shales,	40'	
? *Marcellus* dark shales, *			25'
? *Corniferous lime shales* and impure limestones,			75
? *Caudagalli* gray shales,			50'
Griskany sandstone, rather massive, fossiliferous, etc.,			50.

These formations descend again (northward) but are hidden by heaps of *dêbris* from the outcrop of the great *upper sandstone*, which dips 45° (N.) to make a reef across the river just below J. Bachman's, partly covered and partly uncovered at ordinary stage of water. Rising again it makes another arch, and descends once more into the river at Bordner's run, where only the top 10' of massive yellowish gray sandstone is visible, overlaid by at least 150' of *Hamilton upper shale* thus:—

Genesee black shales (150' visible),	—
Concealed interval,	165'
Hamilton upper shale,	150'
Selinsgrove upper sandstone (10' visible),	—

Ascending the Susquehanna river from the Georgetown anticlinal exposures last described to the anticlinal outcrops at Selinsgrove, a distance of 12 miles, we cross the great Western Middle anthracite (Shamoken) synclinal. Half way stands, on the eastern bank of the river, the high Mahanoy synclinal mountain of *Pocono sandstone* No. X.

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crop reefs across the bed of the river.—No fossils were noticed in it; but no strict search was made for them (G 7, 373). This little anticlinal arc runs between the Tuscarora mountain anticlinal of Perry county, and the Georgetown anticlinal of Fisher's ridge.

* There are no *black* shales; and these dark shales represent the whole of the Marcellus, unless they belong to the Hamilton. In fact it is impossible to classify such sections; even as in this instance only one mile apart. It will be seen directly how utterly this Georgetown section differs from the one at Selinsgrove. Here the Selinsgrove *upper* sandstone lies only 510' above the Oriskany; at Selinsgrove, 12 miles north, it lies 1500' (?) Prof. White suggests the erosion of the Hamilton lower shale, and Marcellus shale, previous to the deposit of the lower sandstone; but there is no sign of aerial erosion (G 7, 372).

Here a bore hole say, 4500′ (IX)+1000′ (IX–VIII)+2500′ (VIII e) 8000′ deep, would strike the top of the *Genesee;* and at say 9100′ the top of the *Selinsgrove* (*Hamilton*) *upper sandstone.* No doubt a hundred variations take place in the Hamilton formation in the great synclinal underworld concealed from all investigation; for bore holes of that depth will never be made through rocks that contain nothing of much value. We may imagine therefore what we please; we shall know nothing more than that when they rise at *Selinsgrove* the strata show the following curiously unexpected section (G 7, 79 and 359):

GENESEE	dark bluish slaty beds, no fossils seen, except a *Discina* (*lodensis?*) 155′ from top,	230′	
	black slate bed,	4′	
	dark shales,	30′=264′	
	Concealed (dip 40,° S.)*,		400′
HAMILTON	*Upper shales*, brown, crumbling; small iron-balls at several horizons; *Athyris Spiriferoides*, *Spirifera mucronata*, *Tropidoleptus carinatus*, *Ambocoelia umbonata*, etc., etc. †	450′	
	Selinsgrove upper sandstone. Spirifera granulifera, *Strophodonta demissa*, *Rhynchonella congregata*.	200′	
	Middle shales dark olive with layers of sandstone,‡	100′	
	dark olive, slate pencil splinters,	25′	
	Selinsgrove lower SS. three layers,§	5′	
	Lower shales olive brown,‖	200′	
	dark; non-fossiliferous,¶	600′?	
	limy, and limestone beds,**	40′=1620′	

* If the dip of 40° be irregular in this concealed interval, diminished, or reversed, the estimate of 400′ must be modified. Part of it must be assigned to the *Genesee;* part to the *Hamilton.*

† This is all there is of Hamilton in the country north of Montour's ridge.

‡ The included hard bluish gray sandstone layers (6″ to 10″ thick) come at intervals of from 3 to 5 feet. The slate pencil fracture of the under shales recalls and repeats the peculiar road-metal characteristic of the *Marcellus* and *Hamilton lower* shales.

§ Separated by thin layers of shale.

‖ The bottom of these olive shales comes up at the 132d RR. mile post.

¶ Dark fissile shales and slates; often exhibiting cleavage, and much weathered; so that the bedding planes can only be occasionally made out to dip about 20° (S. 10° E.); exposed along the RR. as far as the water tank at the mouth of Little run, opposite the middle of Clark's island, i. e. 2100′; therefore thickness not far from 600′.—They look like *Marcellus* slates, but have the *splintery* brownish weathering of both the Hamilton and Marcellus on the Delaware river.—They make nearly vertical *cliffs*, 100′ to 200′ high, along the RR. above its 132d mile post; and exhibit a good deal of *cross cleavage.*—They were searched for fossils by Prof. White in vain (G7, 361, 362).

** This *Selinsgrove upper limestone* (so called in Report G7.) is subdivided

Marcellus, black, fissile, pyritous,*	300′
? *Corniferous limestone*,	65′
? *Caudagalli shale*,	140′
Oriskany sandstone,	—

The Selingsgrove upper sandstone is named from the town on the west bank in Snyder county, opposite the railway cut (on the east bank, a mile below Selinsgrove Junction) where a long, high-pointed ridge reaches the waters edge; the rocks of which make a continuous outcrop, a foot high, across the river bed. It may be divided into

Massive, coarse, yellowish gray sandstone crowded with *Spirifera granulifera*, and several other species of shells,	35′
Massive, coarse, greenish yellow sandstone,	75′
Strophodonta dumosa and *Rhynchonella congregata bed*; a mass of shells,	2′
Flaggy (4″ to 12″), hard, bluish-gray to yellowish-gray sandstone; very massive at bottom for 8 feet,	90′ = 202′

This sandstone mass makes a rough hilly belt across Northumberland county, due east, 18 miles nearly to the Columbia county line; where it rolls over the declining Selinsgrove anticlinal † and returns, north of Elysburg, south of Shamokin creek, to the river at Sunbury.‡

into upper, middle and lower; two sets of impure light gray limestone beds at top and bottom, separated by a middle set of shales.—The beautiful little coral *Aulopora tubiformis* occurs in both top and bottom limestones. *Tropidoleptus carinatus* and *Coleolus tenuistriatus* are confined to the bottom limestone.—locality, the water tank, half-mile below Selinsgrove Junction.

*This very *black*, fissile mass of shales, with *Leiorhynchus limitare* and *Styliola fissurella* in its upper half, no fossils in its lower half, pyritous, with lime balls, near its base is certainly *Marcellus* (G7, 362).

† The Selinsgrove anticlinal axis runs through the village of Elysburg. It crosses the Shamokin just north of Paxinos and Snufftown; and Roaring creek just east from J. Richard's. *Marcellus* is exposed at Reed's Station, Shamokin RR, and westward to the river; for the wide Shamokin valley is excavated in *Marcellus* and *Hamilton lower shales*. Half a mile south of Reed's station crumpled, massive, yellowish gray *Hamilton* (*Selinsgrove upper* ?) sandstone is exposed in RR. cuts for a mile, frequently reversing their dip. Near Paxinos station, the massive sandstones of the ridge dip 20° (S. S. E.) and is very fossiliferous (just west of the station) with *Strophodonta demissa*, *Spirifera granulifera*, *Spirifera mucronata*, broken *crinoids*, and other badly preserved shells.—The *H. upper shales*, crowded with *Tropidoleptus carinatus*, are exposed by the deep cut of the new branch of the Reading RR. just at Paxinos. (G7, 354.)

‡ Here the rocks, not well exposed, dip north from the Selinsgrove anticlinal, descending into the great Catawissa synclinal. At the brook which en-

Shamokin Falls is a ledge of very hard *Hamilton sandstone*, pitching rapidly north, crossing the bed of the Susquehanna, from just below the main portion of Sunbury. The canal dam was built upon this natural wall (5′ to 6′ high) through which low water had worn breaches. Below the dam the river bed is crossed by ribs of bluish gray sandstone almost as hard as quartzite, smoothed and polished by the river, and bored into deep *pot-holes* of every size and shape from one inch to two feet in diameter. (G7, 350).

This north dipping outcrop, from Sunbury westward, makes a ridge across Snyder county, 35 miles, into Mifflin county, doubles back on a south dip and returns to the Susquehanna North Branch three miles above Northumberland; and so continues on eastward up the North Branch Susquehanna valley, cutting across the river bends, past Danville, Bloomsburg, Mifflinville, Berwick and New Haven, to the mouth of Wapwallopen creek in Luzerne county, a total distance (from Northumberland) of 35 miles.*

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ters the river at the mouth of Shåmokin creek are olive brown shales, breaking into splinters, *H. lower shales* (visible) 155′; then several hundred feet concealed under the 800′ wide valley; then *Marcellus black slate* (visible) 135′, concealed 60′, concealed 50′; then the Selinsgrove limestone, etc. (see Fig. 93, G7, 342, 345).—A reverse dip (rise towards the north) makes vertical cliffs, 200′ high, of *H. Lower* dark brown or olive shales all along the railroad from Arnold's run up to where the N. C. RR. crosses Shamokin creek. Here the dip is steep northward to the North Branch and the valley is in *Genesee.*

* Across the *Point* from Branch to Branch, *Hamilton* begins to rise from the N. C. RR. dipping 40° (S. 10° E.) at Gulich's school house. This outcrop upper line of the formation, runs to Reed's S. H. where *Tully limestone* appears in a D. L. & W. RR. cut, 3½ miles up the north bank of the North Branch from Northumberland. From here eastward a level valley, a mile wide, runs south of Montour's ridge; a plain of drifted sand, gravel and boulders, concealing the outcrops of all the *Hamilton, Helderberg,* and *Salina* strata.—Above Chulasky furnace the river cuts a semicircle into Montour's ridge; no *Hamilton* shows.—Across *Rush township* no *Hamilton* shows in the bend; but where the Branch leaves the Chemung bluffs (a mile south of Danville) and crosses the Hamilton flat, appear 1300′ of *Chemung*, 300′ of *Genesee*, 60′ of *Tully limestone*, 100′ of *Hamilton upper shale;* but the rest underneath is concealed. Not a trace of sandstone is to be seen. (G7, 371).—In *Mahoning township* (Montour Co.) a few slight outcrops are seen along the RR. above Danville (G7, 307).—In *Cooper*, the *Hamilton* is concealed beneath the Drift valley south of Montour's ridge (G7, 301).—In *Montour township* (Columbia Co.) the *Hamilton* is concealed beneath the *old buried valley* of the river between Rupert and Danville (7

Here at the next north dipping outcrop doubles back over the axis of the great Montour anticlinal and returns to the West Branch 3 miles below Milton, and crossing into Union county, makes a pointed synclinal ridge.*

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miles). Little outcrops are visible in Fishing creek near the D. L. & W. RR. bridge and in one or two C. RR. cuts (G7, 243–4). The fine Rupert–Catawissa section 4784′ long (G7, 240) only reaches down 125′ into the Genesee.

At *Bloomsburg* Fishing creek and the river have formed a gravel plain 2½ by 1½ miles, in three terraces. The Hamilton beds are covered up everywhere between the RR. and river bank except at one or two points. On the road from the Bloom. I. Co. RR. to the canal, gray-yellow shales (just north of the canal dip 40° (S. 10° E.). The belt of *Marcellus* and *Hamilton together* is 4200′ wide (stretching 50′ beyond the *southern* river bank). At an average dip of only 30° (supposing no rolls, of which they are no signs anywhere) the *Hamilton alone* would measure 2100′ (more than double of what it measures only three miles north, on Fishing creek). The hard *sandy strata* make long ridgy outcrops, running diagonally up the river bed, *each rib of sandrock projecting from one to three feet above the surface at low water*, interrupted by frequent gaps, dipping 35° to 40° (S. 10° E.); the harder ribs extending from the southern shore nearly to the northern shore where they seem to be suddenly cut off as if at the southern edge of an older and deeper channel; but this is rendered improbable by the outcrop of soft shales in the canal banks (G7, 253, 255).—(See Catawissa-Bloomsburg Section, G7, 287.)

In *Scott* township the river channel is entirely on *Hamilton* outcrop (G7, 256).—In *Centre*, the river at Centreville is in *middle Hamilton*; opposite Stoneytown and above the Lime Ridge Ferry) ribs of *Hamilton sandstone* are seen extending diagonally nearly across the river bed; but at Mifflinville the formation is entirely on the south side of the river in Mifflin township (G7, 267).—In *Briar creek* township, the river flows on *Hamilton* and *Marcellus*. At Berwick, at the Luzerne county line, they are seen in the river bed, dipping rapidly southward, worn into ribs by the current, making a series of riffles, falling 5 feet in a few rods. Near the northern shore a fall of two or three feet pours from both sides into a long narrow trough channel cut in some softer beds. A huge spring boils up here, which would make this north side of the river channel *Helderburg* (G7, 273–4; 278).—In *Salem* township Luzerne county, the Hamilton formations makes a broad gentle arch and valley nearly a mile and a half wide, between two ranges of Chemung hills; the valley, or plain nowhere rises more than 150′ or 200′ above the river; whereas the Chemung hills rise 400′ or 500′ above it. The Hamilton rocks are seldom seen because covered with glacial drift. RR. cuts at Hicks Ferry and Beach Haven show ash and dark gray slates and shales, dipping 35° to 40° (N.) with cleavage 55° to 60° (S.). The anticlinal crosses the river a mile north of the mouth of Wapwallopen creek. At the RR. bridge across Little Wapwallopen the top of the *Marcellus* is seen dipping 35° (N. N. W.). Further up river the top of the *Genesee* shows. The concealed interval of 700′ is all that the Hamilton has to come down in, which makes the formation astonishingly thin. In the Wapwallopen valley the formation saddles the arch and sinks with it underground. (See section G7, p. 197; and figure p. 194.)

*On the returning outcrop in *Briar creek* township the three formations

Recrossing the river with a south dip, it runs east again 15 miles, across Montour county, to the Columbia county line; and then back to the West Branch, 6 miles below Muncy.*

Marcellus, Hamilton and *Genesee* make a valley at the foot of the Chemung hills, and dipping nearly 40° (N.) must have a combined thickness of 1200′. On Briar creek the Hamilton shales are lighter and more sandy than the Marcellus (G7, 271).—In *Center*, just north of Connor's tannery, dark olive *Hamilton* shales dip 45° (N. N. W.).—Across *Orange* and *Mt. Pleasant* townships, separated by Fishing Creek, we have nothing left of the *Hamilton* but about 50′ of *H. upper shales* (see the extraordinary section in the text, from G7, 219). And yet in *Hemlock* township on Little Fishing creek (only 3 miles west) 400′ of *Hamilton* intervene between *Tully limestone* and *Marcellus* (see section in text, from G7, 226).—Across *West Hemlock* and *Valley* into *Liberty* townships, the *Marcellus, Hamilton* and *Genesee* united outcrop makes a straight broad valley completely covered with sand and gravel drift; but on Mahoning and West Mahoning creeks *shales* of all three are exposed. In the western part of Liberty they spread across the great Shickshinny synclinal, as a plain, around the west point of the *Chemung* hill country.—Across *Chillisquaque* township, the anticlinal belt two miles wide, runs to the West Branch, and the dark brown shales are well exposed near Fitzler's S. H. and the Evangelical church (G7, 334).

*The *Milton anticlinal* brings the top of the *Hamilton* up to water level of Fishing creek, just south of Stillwater, 11 miles northeast of Bloomsburg, beneath a cliff of horizontal *Genesee black slate* 200′ high (G7, 211).—The axis of the anticlinal runs west, under the village of Rohrsburg, across Greenwood township, to Little Fishing creek a mile below Millville. At Ayresgrove the Genesee rises, and at Sereno sinks again. A belt of Hamilton shales ride the arch, with very low dips, and showing no outcrops. along a valley of erosion, two miles wide, covered with a thick sheet of water rolled boulder and gravel drift (210).—Widening as the anticlinal slowly rises westward across *Madison township*, the drift-filled *Hamilton valley* of erosion parts into two; the narrower southern outcrop, dipping more steeply (S.) making the long valley of Chillisquaque creek; the broader northern outcrop, dipping gently (N.) and waved, making the valley of the upper Chillisquaque as far as Turbotsville.—In *Madison township* the middle of the Hamilton valley is 100′ to 150′ above water in Little Fishing creek which cuts across it. It is therefore *a valley* only in its general relations to the two ranges of Chemung hills which border it on the south and on the north. *Hamilton* shales dipping gently (S.) at Ellis' tannery, and gently (N.) 240 rods further north at Runyan's, designate the position of the axis of the arch. Flat shales are exposed just south of Jerseytown.—Here the *Tully limestone* (full of Hamilton fossils) appears beneath the *Genesee black slates;* and, a few feet under the limestone, in gray shale at the top of the *Hamilton, in a clay-ironstone ball*, was found a shell, *Loxonema delphicola* (?).—South of Thomas' cross roads, the *Hamilton* brown shales are exposed at the roadside, crowded with *Spirifera mucronata* in a state of great perfection—In Anthony township the Hamilton valley (including *Genesee* and *Marcellus*) is four miles wide, and covered with

Making a curve up and down White Deer Hole valley in Union county, it returns east; rolls over the Bald Eagle anticlinal east of Highsville, and begins its long last vertical north and northwest dipping outcrop, which extends into Maryland and Virginia.

A sudden and remarkable change must take place in the *Hamilton formation* between the opposite sides of the Catawissa-Sunbury basin.

We have seen it rising on the Selinsgrove anticlinal 1622′ thick, with a middle member of massive sandrock beds 202′ thick. We are now to see it rising on the Montour anticlinal, at Bloomsburg, seemingly only 600′ thick (but possibly more), with its middle sandstone member so weakened by shales as scarcely to constitute a distinct subdivision.

At its southernmost outcrop north of Harrisburg, we have seen it making the Little mountain; in Perry county rising in zigzag ranges of lofty, rocky hills, covered with forest; at Georgetown and Selinsgrove, stamping the landscape still with a bold topography. Now, suddenly, it hides its softened outcrop underground, and permits a great river to make its bed upon it; not for a moment, as in a gap; but for the length of more than thirty miles. Elsewhere in such marked contrast with the soft *Marcellus* and *Genesee* formations below and above it—a mountain between two valleys—here it resembles them so closely as to lose its special ability for resisting erosion and sinks the outcrop belt, in company with theirs, into a common valley.

No wonder then that the great river of our northern region has seized this opportunity for making its way around the anthracite country to the west, seeing that its direct southward course to the sea was barred against it by the huge outcrops of the *Pocono* and *Pottsville* mountains.

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rolled drift, which seldom allows the shales to be seen. Such is the case also in Lewis and Delaware townships. The Chemung hills which border it on the north rise 400′ to 500′ higher than the low *Marcellus*, *Hamilton* and *Genesee* shale country in the broad valley, all dipping most gently northward away from the *Lower Helderberg* and *Oriskany* Limestone Ridge, on the south.—*Marcellus* black slates are seen on the road from Turbotsville down to the Cemetery, and nearly horizontal *Hamilton* dark brown shales at Russell's road forks (326).

Probably it would have done the same if it had only had the ever soft *Marcellus* belt to work in; but its work was made easy for it by the union of the three members of the *Hamilton*, and the *Genesee* to the *Marcellus*, the breadth of whose single outcrop is here reduced by a dip of 45° to less than 200′. The Delaware river on striking the Kittatinny (Schwangunk) mountain of New Jersey does precisely the same thing in precisely the same way; but it has the Marcellus outcrop to do it in, where that formation is more than a thousand feet thick, and its dip only 30°.

We see now why the New York geologists combined the *Marcellus*, *Hamilton* and *Genesee* as subdivisions of one great *Hamilton formation;* for, toward the north, the great sand rock strata of the middle group were not deposited. Nevertheless the *Genesee* and *Marcellus* shales are everywhere, as well north as south, distinguishable from the *Hamilton proper* shales by their superior muddy fineness, paper-like lamination, disposition to cross slate cleavage, and blackness of color; as well as by some special characteristic fossils.

As for measurements of thickness, when the subdivisions are taken separately along these northern outcrops, they become impossible on account of imperfect exposures. Along the whole course of the North Branch from Sunbury to the Wapwallopen the only section of the slightest value is got at Rupert and Bloomsburg, where thin ribs of sandstone strata, separated by shales, roughen the river bed at low water, and run in long straight lines diagonally from shore to shore, as described in the preceding footnotes (G7, 287).

Genesee dark blue, black and bluish grey, *nonfossil* (?) shale, . .	275′
Tully limestone sometimes fossiliferous, ...	50′
Hamilton, shales and sandstones' in river bed at Bloomsburg ferry, dip 35° to 40° (S.) horizontal distance, ...	1000′.
Marcellus, etc., down to No. VI limestone, 3000′; dip 35°, often 45°; say average 30°, . . .	1500′

Following the outcrop up the river seventeen miles, to the mouth of Wapwallopen creek, where the *Marcellus* rides the anticlinal at water level, the *Hamilton* is evidently still thinner than at Bloomsburg, for it is concealed between exposures in an interval of about 500′ ; as shown by the section (G 7, 196 ; and Fig. 63, p. 194.)

Genessee, dark blue, finely laminated, slate, which only 30′ of the top beds are visible under the *Chemung* rocks; and probably, say 200′, concealed,	230′ ?
Tully limestone, concealed, with the *Hamilton*, concealed,	500′ ?
Marcellus, black shale, 25′ only visible; the rest concealed down to the lowest bed which here remains on the anticlinal above water level; what is below water level is of course unknown,	400′.+

VIIIc. Hamilton N. of Montour's ridge.

If we cross the Montour ridge anticlinal from the Bloomsburg outcrop (south dip) to the Fishing creek outcrop (north dip) a distance of *only three miles*, we find the *Hamilton* reduced to 400′ ; thus (G 7, 226) :

Chemung (possibly *Genesee*) grey shales *much less sandy* than the great mass of *Chemung* above them,	45′
Genesee, dark blue and blackish sandy shales and slates; non-fossiliferous (45° to 50),	27′
Tully limestone, impure blue-grey, weathering dull grey; fossiliferous,	50′
Hamilton, brown, grey, bluish, sandy shales and slates; several horizons of abundant characteristic fossil species,	400′
Marcellus, black, dark blue, slates and shales; quite fossiliferous near the the top (30°)	410′
Oriskany sandstone, No. VII,	6′
Stormville or Oriskany shales,	10′
Lower Helderburg limestone No. VI,	187′

This remarkable section almost staggers our faith in the evidence of surface measurements; for here all the deposits from the No. VI limestone up to the *Chemung*, taken together, measure only 1150′; whereas on the south leg of the arch, only 3 miles distant, they seem to measure more than double that, viz, 2400′. But the failure of deposits seems to be chiefly *beneath*, not *above*, the *Marcellus*. At the same time the *Hamilton* loses. It is but 400′,* as against say 600′ at Bloomsburg; and 1600′ at Selinsgrove! And it loses because its middle member has entirely given out. It is no longer a sandrock formation in any sense of the the term; but a formation of shales and slates, more or less

* This is *above* rather than *below* the truth, for the beds are well exposed throughout, and the dip is never more than 40°, and at several places falls to 35°, and the section is constructed on 40°. (G 7, 229.)

sandy; not black but grey; not dark blue grey but bluish grey, some of it brownish; and charged with characteristic *Hamilton fossils* at various horizons from top to bottom.

Vanderslice's old slate quarry on Little Fishing creek furnishes a rare exposure of the Hamilton formation from top to bottom. Its bluish slate beds were sawed, polished, painted and then baked into dark marble mantels, tables, etc. veined and spotted yellow.*

A richly fossiliferous bed occurs about *100′ below the top*, from which Prof. White collected, and Prof. Claypole identified, the following brachiopod shells :—

Atrypa reticularis, Chonetes logani (var. aurora,) Lingula densa, Orthis penelope, Orthis vanuxemi, Spirifera fimbriata, Spirifera granulifera, Spirifera inæquistriata, Spirifera medialis, Spirifera mucronata, Streptorhynchus chemungensis, Strophodonta demissa, Strophodonta perplana, Tropidoleptus carinatus;—the lamellibranch shells:—Aviculopecten æquilaterus, Eodon (Cypricardella) bellistriatum, Nucula bellistriata; the pteropod shell, Coleopridon (Coleolus) tenuicinctum; the little crustacean shell, Beyrichia punctulifera; the beautiful little trilobites, Dalmanites calliteles, Phacops rana; the small coralline bryozoon, Tæniopora exiqua; and other forms, not determined specifically. "All of these were obtained in about four hours work, and hence it is quite probable that a thorough search would largely increase this [and the following] lists."

At 250′ below the top another shell bed occurs from which three of the same species were obtained (Spirifera mucronata, of course, Orthis vanuxemi, and Eodon bellistriatum) and also Athyris spiriferoides, Pteronites decussatus, Rhynchonella sappho; the first of which (A. Spir.) with Lingula densa (of the list at 150′) was found in fallen slates apparently from beds only 50′ to 75′ below the top, together with Ambocælia umbonata, and Discina media.

* They met with a ready sale, but the company became embarrassed; and before the business was fairly established it was abandoned (G 7, 229).

The Big Fishing creek (Mt. Pleasant) section (G7, page 219) gives 60′ of *bottom Hamilton* dark olive sandy shales, over black Marcellus slates (without fossils) and other shales 425′ down to Caudagalli.

In those bottom Hamilton shales appear the same *Ambocœlia umbonata*, *Spirifera mucronata*, *Tropidoleptus carinatus*, and fragments of *Trilobites* that occur at higher horizons in the Little Fishing creek section (last given above), together with the not yet mentioned *Orthonota undulata*, and *Crinoidal stems;* and these complete our present knowledge of the palæontology of the Hamilton in this district; except the discovery (mentioned in the footnotes) in the extreme top shales, just under the *Tully limestone*, in Madison town, of a clay-ironstone concretion* enclosing a specimen of *Loxonema delphicola* (or a closely allied species) which Prof. White reported as frequently seen by him in the Hamilton. (G7, 77.)

VIII c, Hamilton in Perry county.

The Susquehanna river, four miles above Harrisburg, cuts its noble gap through three parallel mountains, exposing their respective massive central ribs of sandrock, standing vertical, or rather thrown over to the north beyond the vertical. That of the Kittatinny or First mountain, *Medina sandstone No. IV*, has been described. That of the Second mountain, *Pocono sandstone No. X*, will be described in a future chapter. That of the intermediate Little mountain, *Hamilton sandstone No. VIII c*, is the subject of the present chapter. Its relation to the other two will appear from the following section on the east bank of the river, looking east.

Little mountain, however, where the Susquehanna cuts

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* While coarse or massive hard sandrock strata are unknown to the *Hamilton* in this region, some of its beds are layers of compact, brown, bluish gray, or olive colored shales so sandy as to merit the name of fine shaly sandstone strata; and these generally hold numerous concretions of carbonate of iron, clayiron, ironstone balls, one, two or three inches in diameter. The hardest of these beds stand out from the smooth hill slopes, here and there, in little low ledges or cliffs. In weathering they break up and fall down in splinters three or four inches long, like slate pencils.

through it, and for fifteen miles eastward across Dauphin county, and westward through Perry county, is in reality a lofty high-browed terrace to the Kittatinny mountain; formations VI, VII and VIII a, b, which elsewhere separate them by a narrow valley of erosion, not coming up from the underworld at their proper places to outcrop at the present surface.*

Little mountain then is an outcrop of *Hamilton sandstone*, 800′ thick; its sides steep, rough and wooded; its crest a pile of disjointed blocks of the coarser strata; its layers thick and solid, especially in the middle of the formation, becoming thinner and more shaly towards the bottom (where they shoulder up the *Salina shales*), and towards the top (where they overlean against the *Genesee black slates*), as shown in a nearly complete section along the Northern Central railroad on the western bank.†

Fossils shells, characteristic of the Hamilton formation are abundant in a stratum near the middle of the sandstone mass, 360′ above the bottom.‡ *Rensselæria marylandica*, an *Oriskany shell*, can be collected from the sandrock rib which makes the crest.§

Upper Hamilton fossil ore.

At the top of the Hamilton sandstone, along the northern slope of the Little mountain, runs the outcrop of a *fossil ore bed*, about two feet thick; and another is known to lie

* As mentioned in several preceding chapters, it is even possible that the absence here of the *Hamilton lower slate division* may have to be accounted for by whatever explanation will apply to those other missing members of the series.

† See also Mr. Sanders' measured section along the eastern bank.

‡ Exposed near the signal box at the junction of the Penn. R.R. and N. Cent. R.R. a mile below Marysville.

§ Prof. Claypole found this *Oriskany shell* at various places along the *Hamilton sandstone* outcrop; but its discovery here at the Marysville gap is especially important because of the absence of any known Oriskany outcrop from which it might be supposed to come, for miles east and west of the locality. He was unable to distinguish any difference between it and those from the Oriskany. In what region of refuse the animal lived during the intervening ages, until a new invasion of sand enabled it to migrate back to its old habitat, is a question to be answered by future observers (F2, 314).

30′ below it, but the outcrop is no longer exposed (F2, p. 315). *

Dick's Hill outcrop. The Hamilton formation sinks at Marysville to a depth of 15,000′ beneath the Cove basin and rise to the surface again along *Dick's hill*, ten miles distant (N. W.). The gap of the Juniata through Dick's ridge, and the gap of the Little Juniata at Montebello, 4 miles further west, display the formation better on this outcrop than the Marysville gap does on the other. *The middle sandstone* strata make a high, rough, rocky, heavily timbered ridge, along which the dip varies from 30° (S.S.E.) to vertical.† The *upper shales* make the southern slope, dipping 30° (S.S. E).‡ The *iron ore bed* between them and the sandstone is mined at various places; and another much higher bed of fossiliferous shale, which is merely ferruginous elsewhere, is here *a real fossil ore bed*, 2′ thick; brittle, breaking square; holding like the shales which enclose it typical fossil shells; sufficiently good to mine up to 1872, but now abandoned.§

The Perry County fault drops the *Hamilton sandstone* a

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* In the other parts of the county there are three beds, the top one full of *Fenestella*, being sometimes iron bearing; the middle bed contains similar species to the Marysville top bed; the bottom one is that in which most mining is done. This upper Marysville bed was discovered at Lamb's gap, 4 miles west of Marysville, and followed to the river. It no doubt extends westward also from Lamb's gap. In Seidels tunnel it measures 28 inches. A specimen from an old opening showed only 25.5 iron, 45.2 silica; but the ore in the tunnel contains an unusual amount of carbonate of lime, the fossil shells remaining, instead of merely leaving their casts.

† Four miles west of Montebello gap, Dick's ridge is doubled and shifted a mile to the south by two closely folded anticlinals; and then runs on S. W. five miles to the Sherman's creek gap under the name of Rocky Hill. West of Sherman's creek it is called Mount Pisgah where it joins the west end of Little Mountain and makes the prow of the canoe, the high synclinal Knob at Oak grove. Dick's ridge unites the west end of Dick's hill with Round Top the east end of Rocky hill; and here is a shallow gap through the ridge made by a small stream alongside of the Dellville road.

‡ At the eastern end of Dick's ridge where the dip is very high these shales run close under the crest. They are seldom visible but appear to be less fossiliferous than in Centre township (to be described further on). The *Fenestella beds* may be seen at the west end of Dick's ridge, running along the turnpike, east of Rattlesnake hill, nearly to the head of Dark hollow.

§ Rathvone's, Dochterman's, Lickel's, Heishley's old ore banks. Lickel's ore analyzed: Iron 33.1, alumina 8.0, lime 0.3, magnesia 0.8, phosphorus 2.5.

thousand feet against the *Chemuny shales ;* but after making a shallow basin it rises northward to the surface again in Mahanoy ridge ; rides (in the air) over the New Bloomfield anticlinal ; makes Buffalo hills ; again plunges at an angle of 45° to a depth of 10,000′ beneath Buffalo creek ; rises, on the other side of the second great basin, to the surface in Raccoon ridge (west) and Wildcat ridge (east of the Juniata); rides high in the air over the Tuscarora mountain anticlinal ; and descends as Turkey ridge tnto the underworld of Juniata county.

As Little mountain and Dick's ridge have been described as approaching each other westward and uniting in Mount Pisgah, so the Buffalo hills range and Raccoon ridge approach each other westward and come together as Sandy hill ; *Mount Pisgah* and *Sandy hill* being the prows of the two great synclinal canoes ; the formations rising westward into the air.

In the other direction, eastward, Mahanoy ridge and Buffalo hills unite at the Juniata in Half Falls mountain, a compound and faulty anticlinal, which crosses the Susquehana river at Girty's notch in Dauphin county, sinks and carries the formations down beneath the anthracite region. *Wild Cat ridge* and *Turkey ridge* unite likewise on the Tuscarora axis and sink into the underground two miles before reaching the Susquehanna.

Mahanoy ridge zigzags westward into Crowley's and North and South Furnace hills, making a triple prow to a small middle basin widened into three.

In Centre township around New Bloomfield and in Miller township east of it, the high Hamilton sandstone ridges, almost rivaling the mountains of IV and X in attitude, roughness and forestry, give this formation a more important aspect than anywhere else in the State ; for nowhere else do the Hamilton sandstone strata make topography which deserves the epithet mountainous.*

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* At Baileysburg on the Juniata, its heavy solid beds, almost vertical, rise beside the railway for half a mile. The northern slope of the ridge (Buffalo hill) is here however gentle and cultivated nearly to the summit. But the southern escarpment, facing Bailey's run, is too steep and rocky for trees to grow : and any step of the climber may produce an avalanche of loose blocks.

The range of *Buffalo hills* through Centre townships may be taken as the type of these *Hamilton sandstone* ridges. Its sides are steep and well clad in small timber. Its summit is a series of heights, separated from each other by transverse gaps, narrow deep and picturesque, through which country roads follow brooks overshadowed with hemlock-spruces and pines, and bordered with a profusion of sword fern, polypody, ebony spleenwort and other plants which delight in coolness and moisture.* One of these, *Inoculate run*, cuts a long trench diagonally through a zigzag of the ridge two miles southwest of Newport, revealing one of the many anticlinal rolls and little troughs into which the measures of the country are folded.†

Mahanoy ridge also is high, often steep, well timbered and cut with shorter but equally narrow winding evergreen gaps. Its slopes are cultivated to a small height only because of their steepness. The Little Juniata heading up to the west between Mahanoy and Crawley's ridges, flowing then between Mahanoy and Iron ridge, breaks through Dicks hill near Montebello furnace.

Montebello gap shows an important change in the sandstone mass as compared with Marysville; a change which becomes more pronounced from outcrop to outcrop northwestward. At Marysville the whole 800 feet may be called sandstone. At Montebello the upper and lower portions remain sandstone; the middle has become slaty.‡ The little river cuts its way through the upturned *lower shales* and *lower sandstone layers* into the heart of the ridge; then flows for a mile along the *central shaly layers;* and then breaks through the *upper sandstone* and *upper shales* into

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Leaving its valley of erosion between the Oriskany and Hamilton, Bailey's run cuts a deep and narrow gorge diagonally through the mass, down which a picturesque drive descends to the larger, transverse gorge on the Juniata river, set with bold headstones on each side, and filled with the incessant murmur of the river rapids (F2, 270).

* See Mrs. Claypole's list of Perry county plants in F2, 113 to 145.

† See figures on page plate F2, 177. The zigzag is shown on the page plate map (p. 168) but there is a discrepancy in the location of the run.

‡ In Huntingdon county, sixty miles distant, the whole has become shaly except two thin upper and lower sandstones.

the open country. The Hamilton scheme in Perry county then is as follows :—

Montebello gap section, Perry Co.

VIII e,	*Genesee black slate,*		200′
VIII c,	*Hamilton upper slate,* viz:		
	Fenestella beds, ... say	10′	
	Tropidoleptus beds, ... say	10′	
	Non-fossiliferous beds, ... say	200′	
	Paracyclas bed, ...	2′	
	Montebello iron ore, ...	2′	
		——	230′
VIII c,	Hamilton upper sandstone.		
VIII c,	Hamilton middle shaly sandstone.		
VIII c,	Hamilton lower sandstone, in all, ...		500′
VIII c,	Hamilton lower shale, ...		400′ to 500′
VIII b,	Marcellus black shale, ...		100′

The Hamilton lower shales consists 400′ or 500′ of olive sandy shales, with interbedded thin layers of olive sandstone. The deposit taken as a whole is merely a continuation of the underlying Marcellus shales, with a gradual diminution of black mud and increase of light colored fine sand. The lower part of it is a good deal iron stained, and in some places holds thin layers of poor brown hematite iron ore. It has no distinct upper limit; the sand deposits increasing and growing coarser and more solid, until the bed becomes hard and massive. It seems to thicken northwestward.* The shales are soft and easily weathered; consequently their outcrop belt is at the foot of the sandstone ridges, and in the Marcellus valleys. The soil is lean, poor and easily distinguishable by its whitish hue; spreading out over considerable districts (as for example around Little Germany and south of Sandy hill); but usually confined to narrow strips, and much encumbered with *débris* from the slopes of the sandstone ridges.

In Saville township, at the west end of the great Buffalo synclinal, the *Hamilton lower shale* broadens its belt of outcrop around the outside (south and west) slopes of the sandy hills, with a series of low waves. Its naturally poor soil is mostly left in woodland.

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* In the Marysville gap of the Susquehanna it cannot be recognized; but it is possible that it is there so sandy that the lower 300′ of the 800′ sandstone mass of the Little mountain may represent it.

A large part of the middle mass of these *Hamilton lower shales* is here so sandy as to make a *sandstone ridge,* in some places equal in topographical value to the *Hamilton sandstone* ridge proper, but of a very different character as stone; being even bedded thin (1″ to 6″) dark green hard flag-stone layers, splitting evenly, but not capable of being dressed square;* whereas the *Hamilton sandstones* are thick, solid, hard, white (or greenish) beds, breaking irregularly.

The Hamilton sandstone mass has been sufficiently described above. The aspect of its ridges depends much on the strength of the dip. Mahanoy ridge, with its nearly vertical dips, is steep, rugged and uncultivated. Buffalo hills and Dick's hill, with dips of 45°, are more cultivated. At the Sandy hill (west) end of the great basin, where the dips are very gentle, the long southern slopes are covered nearly to the top. Further east along Bilman's (Raccoon) ridge the dip strengthens and the ridge becomes again high and rocky.†

The variability of the *Hamilton sandstone* formation is well shown along the *Wild Cat ridge* outcrop between the Juniata at Millerstown and the Susquehanna north of Liverpool. Hard and solid near the Juniata, making a steep

* Best seen at Shope's quarry, about a mile from Bixler's mills, where 25′ of strata have been quarried for years, affording a tolerably good but unshapely paving stone. Its deep green color and smooth texture contrasts strongly with the yellow Oriskany, white Hamilton and Medina blue limestone and other blocks used indiscriminately in some of the walls (F 2, 326).

† The gap cut through Bilman's (Raccoon) ridge in Saville township, by the upper course of Buffalo creek, is a long, picturesque ravine, finely illustrating the structure of the underground, and the process of surface erosion. The creek, descending from Liberty valley, around the end of Conococheague mountain, strikes the ridge; turns west, cuts obliquely through it, meets a second ridge and avoids it by turning east, and flowing between two ridges until the anticlinal carries them down into the plain; total length of gorge three miles. An accurate topographical map of the little district embracing these Hamilton anticlinal and synclinal folds would be a beautiful and valuable contribution to the science of Erosion.

Raccoon ridge in Tuscarora township is a steep rough forest covered wall, through which Donnally's mill stream cuts a gate. Another long oblique gorge through it, two miles further west, is a wilderness of laurel.

and rugged ridge, the strata grow shaly towards the Susquehanna, making a ridge in Liverpool township cultivated in many places to its very top; numerous good and easy roads crossing it and Turkey ridge in various directions; the united end of the two ridges sloping gently down into the plain within a couple of miles of the river bank.

This is in striking contrast to the *Half Falls mountain range*, only 8 miles further south, the summit of which (500′ above the Juniata) gradually declines, but is still a prominent ridge at Girty's notch where the Susquehanna bends round its end (opposite Fisherville in Dauphin county), and its solid ribs of sandstone make riffles in the river bed.*

Here, at McCormick's new quarry, topmost sandstone beds are soft and easily stripped. The quarry beds under them, solid, some of them slightly conglomeritic, from 1′ to 3′ thick, nearly flat (10° southward), have delivered by an incline plane to the canal bank a great quantity of stone for the new railroad bridge at Shamokin.† The old quarry in Watts township a mile back from the river is not now wrought.

The measured section was obtained in Perry county, but the following order of Hamilton sandstones was observed in the various cross gaps of Centre township:—

Hamilton sandstone section, Perry Co.

Top layers, fine grained, even bedded, green, containing numerous fossils, especially the tribolite *Homalonotus dekayi*, and the branchiopod shell *Tropidoleptus carinatus.*

Concealed strata.

Irony sandstone, very hard, with *Tropidoleptus.*

Concealed strata.

Dark sandstone, with abundance of fossils; among them the slender thorn-like pteropod shell *Tentaculites attenuatus.*

Concealed strata.

Soft yellowish sandstones, with casts of the beautiful shell *Spirifera for-*

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*At low water the only channel through the rocks brings the western shore under the cliffs where the famous outlaw of the last century, Simon Girty, had his cave, and with his friends the Indians commanded the navigation like a robber baron of the Rhine (F, 2,151).

† The overlying *upper shale* is not here seen, but it appears just over the line in Watts township, full of its characteristic *fossils.*

mosa; and other fossils; making it the special fossil bed of the formation. It holds along the Little mountain (or southernmost) outcrop the *Oriskany* shell *Rensseleria marylandica.*

Concealed strata.

Coarse sandstones with indistinct fossils.

Concealed strata.

Bottom beds of fine green sandstone with a large whorled shell, a *Murchisonia* (T2, 203).

The Hamilton upper shale shows a rather abrupt change of deposits from sand to clay.* The upper shales are smoother than the lower, with very little sand (almost none toward the top), soapy to the touch, olive green in color, with ocherous weathered surfaces, and some of them crowded with fossil shells (all of marine types), reddened or blackened with oxide of iron; some of them in fact becoming (locally) *fossil ore beds.*

More than a hundred species of seashells (described and undescribed) were here collected by Prof. Claypole from the *Fenestella beds* and *Tropidoleptus beds* at the top of the formation.†

About 250′ thick in Centre township, these *upper shales*, overlying the *Hamilton fossil ore bed*, are mostly non-fossiliferous. Their uppermost layers (*Fenestella* and *Tropidoleptus beds*) are best exposed on the south side of Mahanoy ridge, a few hundred feet southeast of Barnett's mill, sloping up the abandoned fields from the roadside upwards. A

* The shale outcrop running along the slopes of the sandstone ridges is of course mostly concealed by a general slide of coarse stuff from above; but there are exposures near New Bloomfield on the south side of Mahanoy ridge; near Drumgold's tannery on Sherman's creek in Carroll township; near the Newport road bridge over Iuoculate run; at Toomey's between Buffalo hill and Little Buffalo creek, etc. In Saville township the zigzags of the great Buffalo synclinal show many road exposures of the *Hamilton upper shales*, where large collections of fossils in good condition can be made, *Spirifera granulifera* being especially abundant (F2, 328).—On the Susquehanna, at Girty's notch, Watts township, the *Paracyclas* shales have their best exposure in the county at the first ore diggings, where an abundance of their fossils can be collected. The two other ore banks throw out less shale. Near the third (100 yards south of it) the *Tropidoleptus* bed shows its color and fossils (F2, 383).

† No sharp distinction can be made between these; they graduate into each other; but the *Fenestella* is especially abundant at the top. The *Tropidoleptus* prevails in the next lower set of beds; but it ranges down to the sandstones, in the upper layers of which it is exceedingly plentiful.

harvest of various species of coral forms (*Fenestella*) may be gathered in the green shales, some easily splitting, others tough, on the surfaces of which the bright rusty red, or black fossils are very conspicuous.*

From another exposure at Toomey's on Little Buffalo creek the whole thickness of the *upper shales* can be examined, dipping 40° (N. N. W.) thus :—

Genessee dark shales (black when wet) very fine and smooth. Greenish soft shale, with *Styliola fissurella*. Rusty soft thin layer with *Fenestella*. Sandy soft beds (marked with bright red oxide of iron), with *Brachiopod shells*, *Crinoids*, *Trilobites*, etc. Soft scaly beds with few fossils. Sandy greenish shales. Under all *Hamilton Montebello upper sandstone*.

The *fossil ore* at the bottom of the *Hamilton upper shale* is in reality the lower part of the *Paracyclas shale bed*. It is usually about 2′ thick; its upper half a fairly good hematite deposit; the lower half very *sandy*, *fossiliferous ;* both taken out together, and only good to mix with other and better ores.†

VIII c, Hamilton in Juniata county.

All the features displayed by the formation in Perry county may be seen in Juniata county along the Tuscarora valley, the floor of which is traversed by a number of parallel upfolds and basins pointing up westward. *Turkey ridge*, made by the Hamilton standstone, runs about eleven

* About 20′ of these beds rise at 92° (N.) ; the *Fenestella* crowding the upper portion, beautifully preserved, but soft and fragile ; near the middle *Vitulina pustulosa* abounds ; in the lower more sandy portion *Tropidoleptus carinatus*.—Other exposures occur along the road from New Bloomfield to Little Germany; on branch road to Perry furnace ; at McKee's; S. Brown's; W. Brunner's brickyard where crushed and distorted fossils have been thrown out of ditches (F 2, 207).

† It varies greatly in thickness; often disappearing; easily traced by its position between the sandstone and shale ; scarcely visible along the whole Wildcat, Raccoon, Sandy hill range; beginning to show at the west end of Buffalo hills; once mined near Manorsville; at Juniata furnace south of Newport; at Girty's notch on the Susquehanna; on south side of Half Falls mountain at the Juniata ; along Mahanoy ridge at Cook's and Peterman's ; absent west of New Bloomfield ; mined on south side of Crawley's hill north of Perry Furnace ; disappears again ; reappears beyond the fault on south side of Dick's hill ; better and larger where once mined at Dachterman's, Dickel's, Rathvon's; scarcely seen south side of Pisgah hill ; thickest and best along the Little Mountain at Seidel's mines Marysville, where its originally limy nature is made evident (F 2, 100).

miles, with a crest about 150′ above the valley, but getting lower as it nears the Juniata river. West of the river the valley is made of the lower shales; but after widening westward it takes in some sandstone rocks along its middle line. At Honey Grove even beds as high as the Chemung are preserved. No description in words would be of much use. The reader must consult the new colored geological State map, and Mr. d'Invilliers' Report F3, 1891.

VIII c, Hamilton in Snyder and Mifflin counties.

In Snyder county, beneath 300′ of Genesee dark slates appear 1000′ of Upper Hamilton slates and shales; and beneath those, on both sides of Shade mountain, another 1000′ of sandy shales and several beds of massive sandstone. See the already given Selinsgrove sections.

In Mifflin county there are no Chemung ridges; consequently the Genesee and Upper Hamilton slates make the valleys on each side of the central Portage ridge; while the Middle Hamilton is not a sandstone mass and only makes low hills, in striking contrast to its topography in Perry county. The thickness of the entire series of VIII a, b, c, d, e, f, g, (*i. e.*, from Marcellus to Chemung, both inclusive), is estimated by Mr. d'Invilliers (F3, p. 48) at only 2500′.

VIII c, Hamilton in Huntingdon county.

Southern Huntingdon is a continuation of Mifflin county on the west; the Lewistown or central Juniata river valley running on as Aughwick valley.

Mr. Ashburner's report in F, p. 223, describes the Hamilton shales as they sweep round the S. W. end of Jack's mountain as only 685′ thick, thus:—(1) at the top, mostly gray flags and shales, with fossils, 250′;—(2) hard, massive, greenish grey and flaggy olive sandstone, graduating downward into light olive slaty sandstone, with iron stained surfaces and fossils,* 85′;—(3) mostly massive and flaggy

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**Aviculopecten princeps, Chonetes mucronatus* and *coronatus, Grammysia, Sp. granulifera* and *mucronata, Tentaculites,* and *Spirophyton* (*Taonurus*) *caudagalli.*

gray sandstone with fissile shale partings, and fossils, 250′;—(4) micaceous thin flags, with shale partings, 100′; =685′*

After turning the southwest end of Jack's mountain the Hamilton outcrop runs back northeast along the narrow Hare's valley between Jack's and Sidling mountains to the Juniata at Mapleton, where the dark Genesee slates (145′ thick) stand out boldly and vertically between the Portage flags on one side and the Hamilton shales, flags and sandstones on the other, so that the subdivisions of Prof. White are easy to make out. The Tully limestone (5′) at the base of the Genesee, helps the definition; as does also the coral bed in the upper Hamilton shales.

Keeping on northeast, mostly north of Mill creek, to the great bend of Standing Stone creek, the Hamilton outcrop swings round across the great synclinal, and returns to the Juniata at Huntingdon, and runs on southwest along the south side of the Crooked creek valley opposite McConnelstown, past Coffee run station and Rough and Ready into Bedford county.

Prof. White's study of this long outcrop resulted in the following classification copied verbatim from his report on Huntingdon county, T3, 1885, pp. 109 to 113.

The Hamilton upper shales.

These yellow, greenish and gray beds, 200′ to 250′ thick, everywhere rest on a sandstone which makes a continuous ridge; but the upper part of the group next the Genesee slate is almost always concealed by the fallen fragments of Portage sandstone, so that the division plane between Genesee and Hamilton from which to measure the two groups is seldom got. These upper shales are the specially fossiliferous subdivision of the Hamilton formation.†

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*His Portage series, 1450′ thick, and his Genesee series 325′ thick, overlie and his Marcellus series 875′ underlie his Hamilton series. There is in fact no way to subdivide satisfactorily this 3335′ of shaly, flaggy measures, because it has no massive sandrock subdivision in it.

† Under the Mapleton railway bridge the uppermost 50′ are so crowded with fossil shells that Prof. Claypole and myself collected in one hour specimens of Dalmanites colliteles, Loxonema delphicola, Loxonema terebra, Modiomorpha concentrica, Lunulicardium fragile, Eodon bellistriatus, Pal-

The sandy flags (25′) in the Mapleton section are sometimes sufficiently hard to make a low ridge on the surface.

The *coral bed* (4″ to 6″ thick) in the middle of this shale series suggests a comparison with the great *coral reef* near the top of the Hamilton proper described in Report G[6] on Pike and Monroe counties.*

The Hamilton upper sandstone.

These sandy beds (30′ to 40′ thick) make a low ridge in the valley; are of bluish gray or drab, occasionally buff or dark yellowish-gray; sometimes contain 10 or 15 per cent of lime; and are always crowded with impressions of the long corrugated fronds of a cock-tail seaweed, *Taonurus* (*Spirophyton*) closely allied to if not identical with that which gives name to the *caudagalli* grit (many hundred feet further down in the series) or intermediate between it and *Taonurus crassus*. The plant is sparingly exhibited in the higher and lower portions of the Hamilton formation, but covers almost all the surfaces of the layers of this upper

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œoneilo constricta, Actinoptera decussata, Tropidoleptus carinatus, Athyris spiriferoides, Spirifera mucronata, Ambocoelia umbonata and Strophodonta perplana. From the upper half of these shales at Huntingdon (near where the road leads into the cemetery) the following forms were obtained and indentified by Prof. Claypole: Dalmanites calliteles, Palœoneilo constricta, Tropidoleptus carinatus, Athyris spiriferoides, and Spirifera mucronata (five of the species found at Mapleton); also Orthonata undulata, Leiopteris bigsbyi, Leiopteris rafinesqui, Nuculites elongatus, Nuculites triquetra, Cardiomorpha bellatula, Cardiomorpha zonata, Cardiomorpha concentrica, Cardiomorpha cordata, Spirifera fimbriata, Chonetes setigerus, Pleurotomaria capillaria, Nautilus buccinum, Bellerophon leda, Homalonotus dekayi, Phacops rana, and Beyrichia punctulifera. At about 50′ beneath the top of these shales again near Grafton, Penn township, I obtained the following species identified by Prof. Claypole: Dalmanites colliteles, Spirifera mucronata (both found at the other two localities); Chonetes setigerus, Nuculites triquetra, Homalonatus dekayi (all three found also at the Huntingdon locality); Modiomorpha complanata, and Tentaculities attenuatus. (White.)

*On p. 107 Prof. White gives the following section of these upper shales: Sandy shales with *Homalonotus dekayi*, *Heliophyllum halli*, *Spirifera*, and *Stictopora*, 70′: sandy crinoidal flags, 25′; sandy gray shales, 25; coral bed, with *Heliophyllum* and *Cystiphyllum*, only 4 to 6 inches thick; dark, brown shales quite fossiliferous near the bottom, 85′; dark grey shales, sparingly fossiliferous, 50 on sandstone.

sandstone. *Spirifera ziczac* and *crinoidal* fragments are also abundant in them everywhere; and *Homalonotus dekayi*, *Phacops rana*, and *Orthonota undulata* have also been found in them. These sandstone beds are visible on all the roads which run east from the Huntingdon and Broad Top railroad; and are conspicuous at Rough and Ready station, where they make a ridge along the middle of the valley 50′ to 75′ high. They make also the island-like bluff of rock where the county road passes underneath the railroad opposite Huntingdon; and where they have been extensively quarried for rip-rap and road-fills; although some of them are cut away by Muddy creek.

The Hamilton middle shales.

These soft beds usually make a deep little vale between the upper and lower sandstones. They are 200′ to 225′ thick; dull gray; decomposing into small chips, called "slate-gravel," the best material for roads in the state. The first H. & B. T. R.R. cut, half a mile south of the Huntingdon bridge, has furnished a mass of the slates for the "long fill" across the river valley. *Univalve shells* are characteristic of these Hamilton middle shales, from which most of the Hamilton species have come; they are sparingly scattered through the whole mass of shales, but become numerous near the bottom layers; through which the railroad is cut for a long distance between Rough and Ready and Cove stations, approaching the Bedford county line. Here White got many fossils, weathered out of the shale, from 1 to 10 feet above the underlying sandstone; which were identified by Prof. Claypole.*

* Spirifera granulifera, Spirifera medialis, Spirifera mucronata, Rhynchonella prolifica, Lingula tigea? Chonetes logani, var. aurora, Tropidoleptus carinatus, Pleurotomaria sulcomarginata, Pleurotomaria capillaria, Loxonema terebra, Loxonema delphicola, Cyclonema hamiltoniæ, Bellerophon leda, Palæoneilo emarginata, Palæoneilo perplana, Nucula corbuliformis, Cardiomorpha concentrica, Cardiomorpha bellatula? Pterinea flabellum, Leiopteris rafinesqui, and Actinodesma subrectum; which last occurs only at the very base of the shale, almost in contact with the sandstone.

The Hamilton lower sandstone.

The ridge which these hard beds (50′ thick) make along the valley can be particularly well studied between Cove station and Coffee run, as the railroad in following it runs sometimes on one side and sometimes on the other side of it; but from McConnellstown station to Huntingdon the ridge is left to the west. North of the river the ridge reappears and separates the Genesee subvalley of Stone creek from the Marcellus subvalley of Muddy run. The hill behind Huntingdon is largely made of the lower sandstone; but the part covered by most of the Cemetery grounds, of the upper sandstone; the two here make different portions of one ridge. The layers (6 inches to 2′ thick) of dark-gray or yellowish brown stone seldom aggregate less than 50′; the upper ones being often quite fossiliferous in streaks; *Rhynchonella* and *Spirifera* specially abundant; as at Cove station. This group may represent the *Selinsgrove upper sandstone* (200′ thick) making ridges 500′ to 700′ high in Northumberland county; and the *lower sandstones* of the 800′ group which makes the rocky ranges of Perry county. (See Reports G^7 and F^2).

The Hamilton lower shales.

These more or less sandy beds (75′ to 100′ thick) are well exposed at Huntingdon on the graded road which turns up Muddy run; again at Coffee Run station, where it has been quarried for the "long fill" across Coffee Run valley; and again almost completely exposed from Cove station along the road to Powell's iron and limestone mines. They are everywhere sparingly fossiliferous, and the species badly preserved. At Coffee run were collected *Amcocœlia umbonata*, *Rhynchonella horsfordi*, *Pteronites lævis*, *Leiorhynchus limitare*, *Goniatites sp.?* *Orthis vanuxemi*, *Orthoceras subulatum*. A small *bryozoon* in delicate rounded patches occurs frequently. Limy layers in the group are well exhibited on the road from McConnellstown to the station. Two or three lime-sand layers can be followed for some miles north and south of the river at Huntingdon, 6″

to 1′ thick, separated by 2′ to 5′ of shales. They show just below the 203d RR. mile post. They are so low in the series that Marcellus fossiliferous shales appear 5′ to 10′ under them. Were it not for these fossils one might carry the Hamilton 200′ or 300′ lower down; and this may have been done in other districts of the state.

As the whole Hamilton series extended originally from the top of the Genesee to the bottom of the Marcellus, Prof. White made calculations of thickness at seven exposures in Huntingdon county (T3, p. 107) where he found the Genesee 145′, 200′ and 250′; the Tully 5′; the Hamilton proper 550′. 585′, 600′, 605′ 613′, 630′, 643′, 665′; the Marcellus 600′, 625′, 650′, 700′, 725′; and got the following totals: 1450′, 1455′, 1465′, 1468,′ 1480,′ 1500′, 1513′, 1535′, a sufficiently remarkable result, considering the size of the area.

VIIIc in Bedford and Fulton.

The Huntingdon outcrop runs south in front of Tussey mountain into Maryland. Another outcrop runs in front of Wills and Dunning's mountains from the Maryland line into Blair, and in front of Bald Eagle mountain all the way from Hollidaysburg to Muncy in Lycoming county.

Prof. Stevenson describes the Hamilton in Bedford county in his Report T2, p. 81, as "a rudely oval belt surrounding the Savage mountain anticlinal in Chestnut ridge; strips exposed on the west side of Wills and Dunning's mountains, in the Bedford synclinal, and along the east foot of Warrior's ridge. The lower part of the group is exposed on the Pigeon cove anticlinal. It is again exposed around the Blacklog and Cove anticlinals in Fulton county. In the Saxton section, under 200′ of Genesee are 793′ of Hamilton shale, and then 794′ of Marcellus shale. The Hamilton shale are rather laminated sandstones varying much in hardness, making a well defined ridge almost as high as that of the lower Chemung beds; very hard on the east side of Pigeon cove, where they resist erosion almost as well as the Portage flags do. Apparently thin in the imperfect exposures alongside of the McConnell's Cove anticlinal. They are often exposed in Bedford county, and show little variation. They are usually fossiliferous. *Tropidoleptus carinatus*, *Sp. mucronata*, *Leiorhynchus*, and *Streptorhynchus chemungense* (or a variety) prevail throughout. Species of *Bellerophon* and *Pleurotomaria* are abundant in the highest beds. A fine *Spirophyton* (*Taonurus*) occurs at several horizons.

It is unnecessary to follow the Hamilton outcrop eastward past Altoona to Muncy in Lycoming county, where it returns into Union and Snyder and has been described above; further than to say that Prof. Ewing in the Report of Centre Co., T4, p. 432, speaks of a petroleum smell in a probably black Marcellus shale in Bald Eagle creek 2 m. S. of Unionville. Near by numerous outcrops of Hamilton iron-stained shale are overlaid by limeshales grading upward into limestones, which predominate at the eastern limit of the county, and hold *Trop. carinatus*, *At. reticularis*, *Phacops bufo*, *Orthonota undulata*, *Strombodes distortus*, *Chonetes*, *Discina*, etc. The dip is 20° to 40° N. W.; but near Julia the dip is overturned (?) to 45° S. E. and 80° S. E. or else there is a small sharp synclinal. Near Matilda *Lunulicardium fragile*, a Genesee fossil, is seen.

CHAPTER LXXXIX.

No. VIIIc. Hamilton fossils.

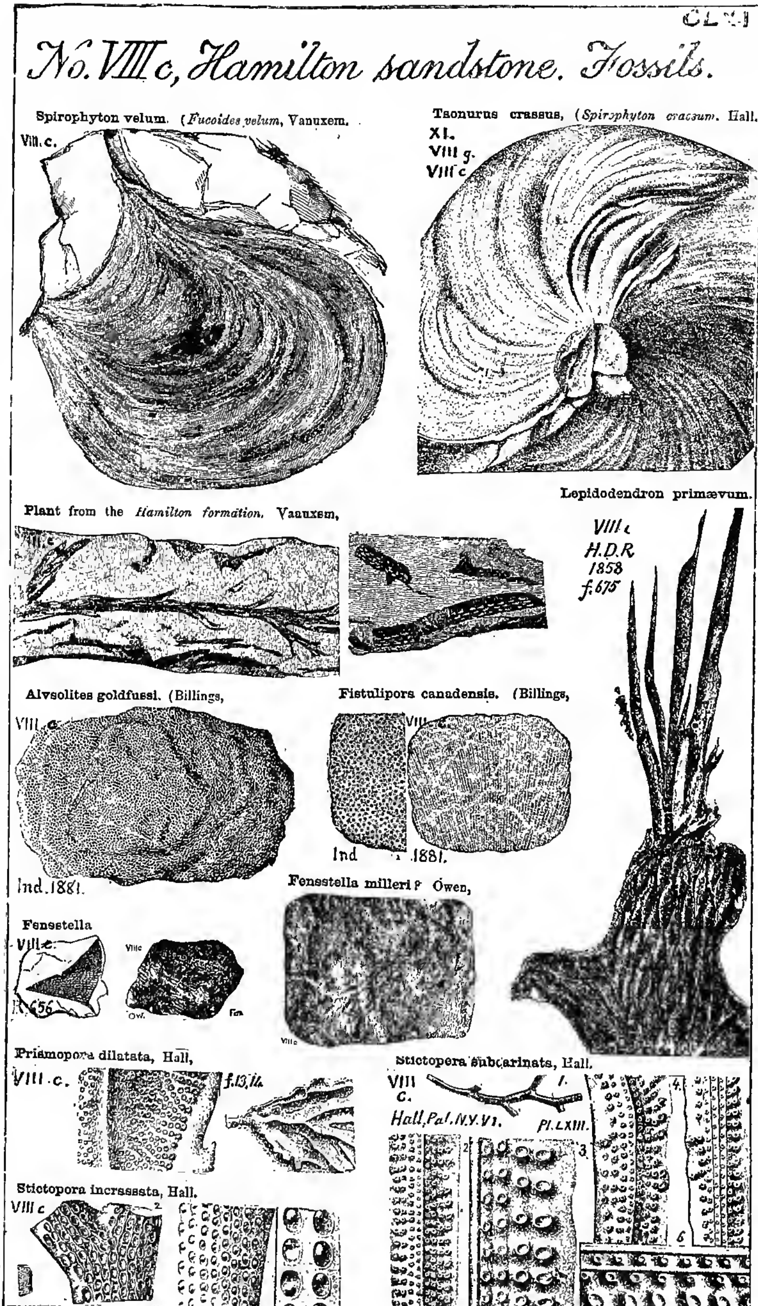
In New York the broad outcrop of the formation has furnished an abundance of generic and specific forms, most of them plentiful in Pennsylvania. They have been so admirably figured and described by Hall and Vanuxem in their original quarto reports of 1842, 1843, and by Hall in the superb volumes of his Palæontology of New York, that I will only mention those most common and therefore most useful to the field geologist and student. A few rare kinds however may be discovered in our state by skilful and zealous observers. Lists of the genera and species recognized in various districts of Pennsylvania will be given further on; and reduced figures of most of these forms can be seen on page plates CLXI to CLXX here following:

Seaweeds of the Caudagalli age continued to live and float on the open sea and be buried in the Hamilton sandy shale deposits; but their shape had somewhat changed from the simple Cocktail to the Curtain supported at both ends, *Taonurus* (*Facoides*) *velum*, Vanuxem.*

A land plant is figured by Vanuxem (p. 157) from fragments found in considerable abundance S. W. of Albany, and occasionally elsewhere in that state. The *Stigmaria* of the Coal Measures evidently had far more ancient ancestors.

The Corals of the Hamilton are found in its upper part, and chiefly in the *Encrinal beds* which are full of the broken and disjointed stems of stone lilies floated or rolled from a distance, and some of them of extraordinary size.—

* Locally in considerable abundance; form better preserved and defined; surface continuous but wavy; stem unmistakedly that of a fucoid or seaweed. Vanuxem's collecting ground was Lewis' quarry near Solsville on the Shenango canal. I think it has not been seen in any Pennsylvanian outcrop of the Hamilton.



No. VIII c, Hamilton sandstone. Fossils.
Spirophyton velum. (Fucoides velum, Vanuxem.
VIII. c.
Taonurus crassus, (Spirophyton crassum. Hall.
XI.
VIII g.
VIII c
Lepidodendron primævum.
VIII c
H.D.R.
1858
f. 675
Plant from the Hamilton formation. Vanuxem,
Alveolites goldfussi. (Billings,
VIII. c
Ind. 1881.
Fistulipora canadensis. (Billings,
VIII c
Ind
1881.
Fenestella milleri ? Owen,
Fenestella
VIII c.
Prismopora dilatata, Hall,
VIII. c.
f. 13, 14.
Stictopora subcarinata, Hall.
VIII c.
Hall, Pal. N.Y. VI.
Pl. LXIII.
Stictopora incrassata, Hall.
VIII c

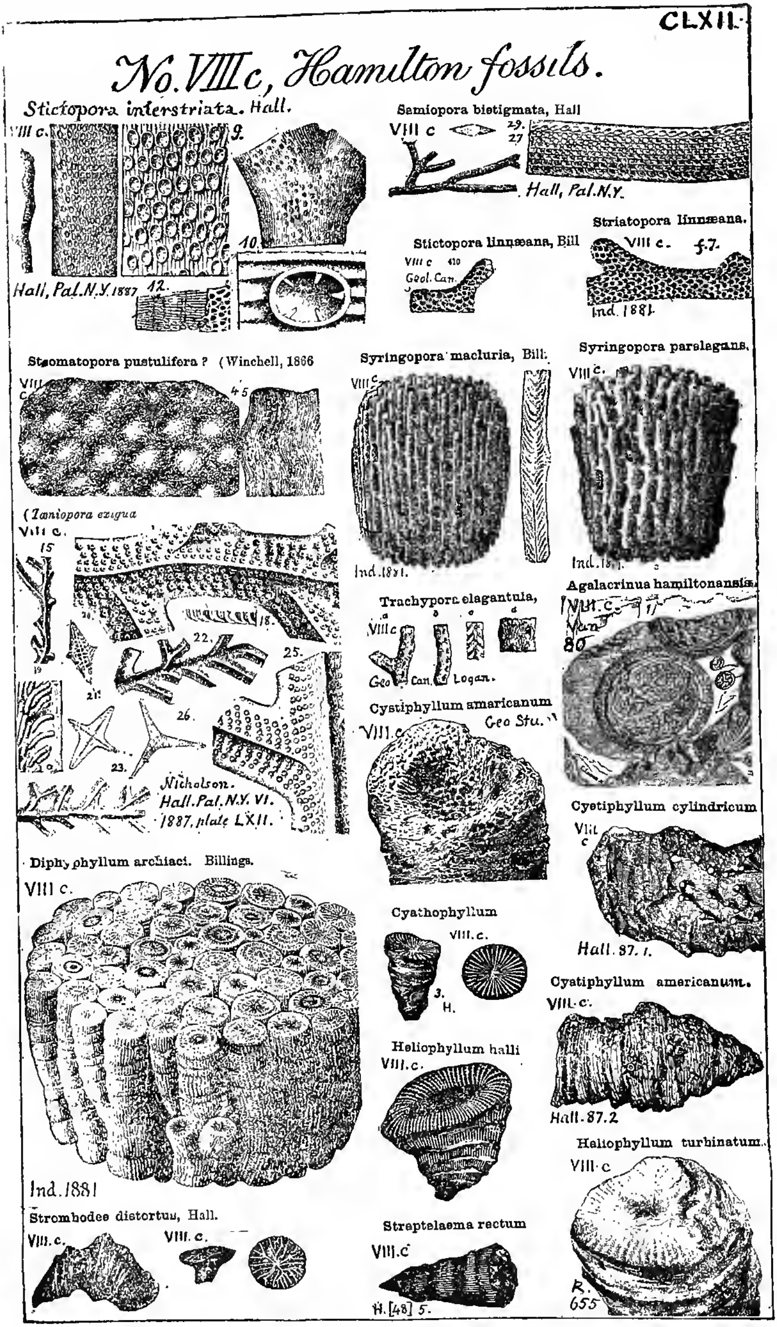
The overlying *Moscow shales* furnish fragments and whole specimens of *Cystiphyllum americanum* (*cylindricum*, Lonsdale, Sil. Research, 691) on which are seen growing the parasitic *Aulopora tubiformis*, in England as well as in New York, and also stone lilies.* Also, *Heliophyllum halli* (*Strombodes helianthoides*, Phillips ; *Cyathophyllum helianthoides*, Goldfuss). Also, *Strombodes distortus*, a peculiarly bent and wrinkled cup coral. Also, *Streplelasma* (*Strombodes*) *rectum*, a straight coral, with a very deep cup, thin edges, and lined lengthwise, often in pairs, but never united, and very abundant. Also *Zaphrentis* (*Strombodes*) *simplex*, with a shallow cup, and resembling the *Strombodes plicatum* of the older Corniferous limestone age, *VIII a*.

Sea urchins of curious and beautiful forms and sculpture, called by Vanuxem *Agelacrinus hamiltonensis*, lived in little colonies, or groups.†

Bryozoa of many genera and species were extraordinarily abundant in Hamilton waters, some branched, some simple, some jointed, some encrusting shells as lichens do rocks, others erect and independent; most of them named by Hall in his pamphlet report of 1883 thus:—Paleschara intercella, reticulata, variacella, amplectens, (Lichenalia ?) pertenuis; Trematopora scutulata, transversa, polygona, tortalinea, subquadrata, perspinulata, claviformis, orbipora, granistriata ;—Callopora bispinulata, bipunctata, internodata, hemispherica;—Thallostigma variapora, confertipora, scrobiculata, serrulata, umbilicata, longimacula, multacultata, digitata, densa, micropora, segregata, striata, decipiens, subtilis, plana, spheroidea, triangularis, inclusapora;—

* In Hall, p. 209, a figure shows part of a lily stem which grew on a *Cystiphyllum* while the coral was alive and erect, the basal discs of two others which rooted themselves on it after it had died and fallen.

† He found six of them together in a Madison county quarry, three of which were an inch in diameter, and one showed its five radiating arms and its star-shaped mouth. In the same rock were many *Spirifera* (*mucronata*, *prora*), *Chonetes carinata*, *Homalonotus dekayi*, etc., most of them replaced by red oxide of iron finely contrasting with the grey rock. (See his fig. of 1842, p. 306, reproduced in Dict. Foss. Pa. Vol. I, p. 8, and reduced on plate 162 of this summary.) For another species, *A. holbrooki*, see U. P. James in Jour. Cin. S. N. H. X, No. 1, 1888.


CLXII.
No. VIII c, Hamilton fossils.
Stictopora interstriata. Hall.
VIII c.
9.
10.
12.
Hall, Pal.N.Y. 1887
Semiopora bistigmata, Hall
VIII c
29.
27
Hall, Pal.N.Y.
Striatopora linnæana.
VIII c.
f.7.
Stictopora linnæana, Bill
VIII c
410
Geol. Can.
Ind. 1881
Stromatopora pustulifera ? (Winchell, 1866
VIII c
45
Syringopora macluria, Bill.
Ind. 1881.
Syringopora perelegans.
VIII c.
Ind. 1881.
(Taeniopora exigua
VIII c.
15
18.
22.
25.
21.
26.
23.
Nicholson.
Hall. Pal. N.Y. VI.
1887, plate LXII.
Trachypora elegantula,
a
b
c
d
VIII c
Geo Can. Logan.
Agelacrinus hamiltonensis.
VIII c.
80
Cystiphyllum americanum
Geo Stu.
VIII c
Cystiphyllum cylindricum
VIII c
Hall. 87. 1.
Diphyphyllum archiaci. Billings.
VIII c.
Cyathophyllum
VIII.c.
3.
H.
Cystiphyllum americanum.
VIII c.
Heliophyllum halli
VIII.c.
Hall. 87.2
Heliophyllum turbinatum.
VIII c
Ind. 1881
Strombodes distortus, Hall.
VIII. c.
VIII. c.
Streptelasma rectum
VIII. c
H. [48] 5.
R.
655

Lichenalia stellata, foliacea, cultellata, constructa, colliculata, (Ceramopora) clypeiformis, (C.) imbricella;—Stictopora incisurata, obliqua, indenta, palmipes, sinuosa, multipora, subrigida, crenulata, granifera, interstriata, permarginata, incrassata (?), scutulata, dichotoma, (Tæniopora) exigua (Nich.), (Prismopora) dilatata, (Semipora) bistigmata,, (Acrogenia) prolifera ;—Hederella cirrhosa, canadensis (Nich.), filliformis (Bill.), magna;—Ptilionella conferta, penniformis, nodata ;—Hernodia humifusa ;—Ptilopora striata, nodosa ;—Glauconome carinata ;—Thamniscus pauciramus ;—Botryllopara socialis (Nich.).†

The *Brachiopod* shells peculiar to, or highly characteristic of the Hamilton formation, enable the field geologists to recognize its outcrop quite as well in Pennsylvania and Virginia as in New York.

Spirifera (*Delthyris*) *mucronata* (the sharp-pointed), called by people *the fossil butterfly*, is most striking and common of all the brachiopod shells, and a sure guide to the outcrop of the upper half of the Hamilton formation, which it pervades. It has from 24 to 30 rounded ribs, and varies much in shape, being thin, long and pointed in sandy rocks, and short and fat in shale : as shown by Hall's figures (1844, pp. 150, 198, 205) reduced on plate 165, page 1292 of this volume. In Pennsylvania it grew in equal abundance, and all the Hamilton outcrops can be located on the state map by the most superficial observation of stones in ploughed fields pitted with the casts of this shell, the shell itself being seldom preserved. Myriads of rock specimens cover the hill slopes, each one a mass of its perfect or imperfect casts.

Spirifera medialis (*Delthyris medialis*, and *eatoni*) comes next in abundance and ubiquity, a larger, coarser and thicker shell, but less variable ; the young frequently seen mixed with the adult in great numbers. Its upper valve is semi-circular, high in the middle ; lower valve very convex ; beak prominent ; 32 to 40 rounded ribs, crossed

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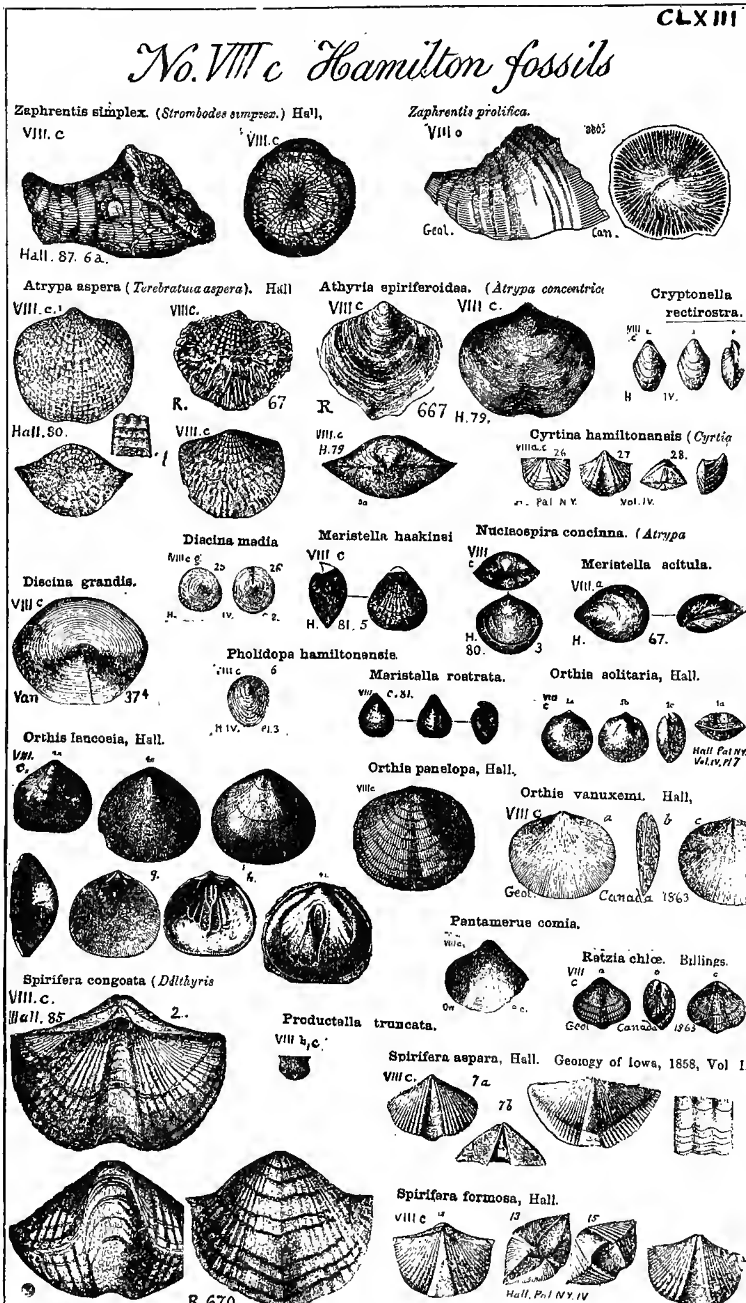
† The typical differences between Stictopora, Ptilodyctia and Acrogenia are shown by Hall's figures on p. 46, 1885.


CLXIII
No. VIII c Hamilton fossils
Zaphrentis simplex. (Strombodes simplex.) Hall,
VIII. c
VIII. c
Hall. 87. 6 a.
Zaphrentis prolifica.
VIII c
Geol.
Can.
Atrypa aspera (Terebratula aspera). Hall
VIII. c.
VIII c.
R.
67
Hall. 80.
VIII. c
Athyris spiriferoides. (Atrypa concentrica
VIII c
VIII c.
R
667
H. 79.
VIII. c
H. 79
Cryptonella rectirostra.
Cyrtina hamiltonensis (Cyrtia
26
27
28.
Pal. N. Y.
Vol. IV.
Discina media
Discina grandis.
VIII c
Van
37
Meristella haskinsi
VIII c
H.
81. 5
Nucleospira concinna. (Atrypa
VIII c
H.
80.
3
Meristella scitula.
VIII. a
H.
67.
Pholidopa hamiltonensis.
VIII c
6
H IV.
Pl. 3
Meristella rostrata.
VIII c. 81.
Orthis solitaria, Hall.
Hall Pal N.Y. Vol. IV. Pl 7
Orthis lancosia, Hall.
VIII. c.
g.
h.
Orthis penelopa, Hall.
VIIIc
Orthis vanuxemi. Hall,
VIII c
a
b
c
Geol.
Canada
1863
Pentamerus comis.
Retzia chloe. Billings.
VIII c
Geol
Canada
1863
Spirifera congoata (Delthyris
VIII. c.
Hall. 85
2.
Productella truncata.
VIII b, c.
Spirifera aspera, Hall. Geology of Iowa, 1858, Vol I,
VIII c.
7a
7b
Spirifera formosa, Hall.
VIII c
13
15
Hall, Pal NY. IV
R. 670.

by numerous lines (representing the edges of the plates of growth) slightly arched upon the rib; often a scratch along each rib half-way from base to beak. Area large, curved and scratched crosswise (Hall, p. 208).

Spirifera macronota can be easily recognized by its broad area, narrow aperture, many small plain ribs, and strong growth-plates, the edges of which cast a strong shadow to a slant light.

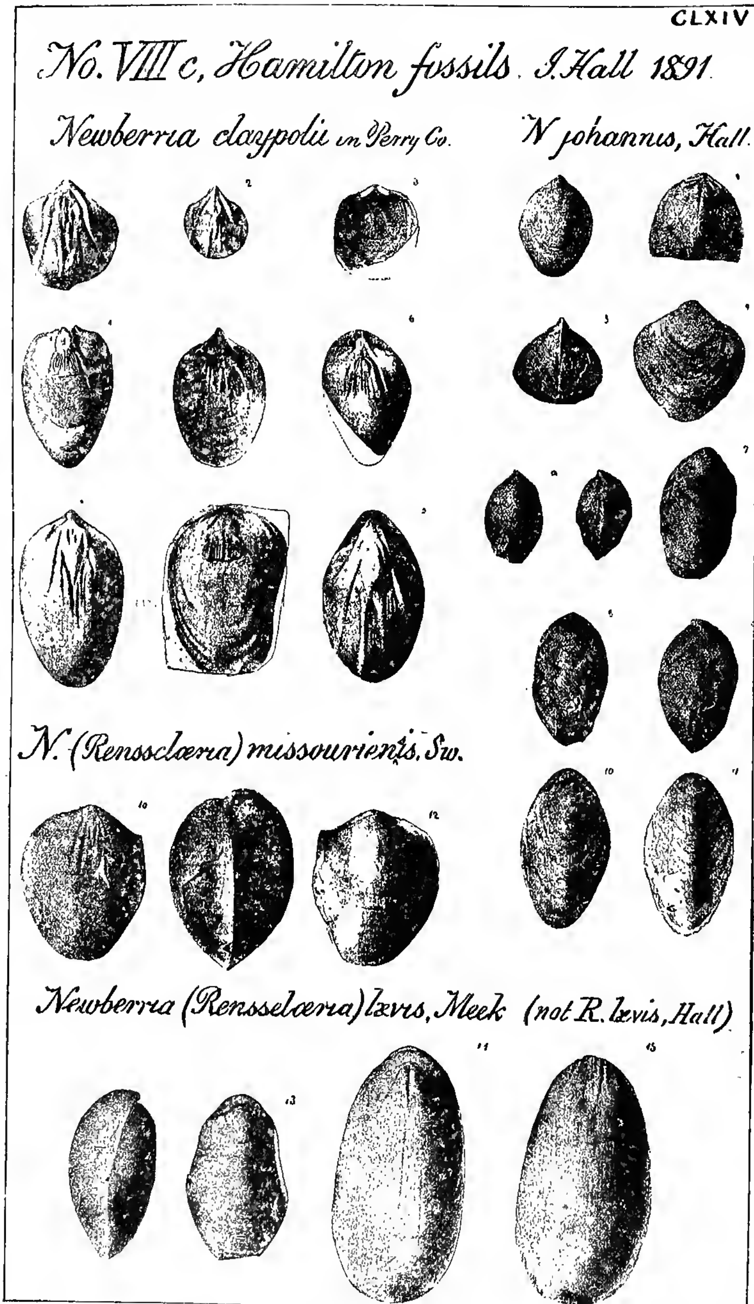
Spirifera granulifera is a large shell not uncommon, but usually pressed out of its original shape by movements in the rock which have rubbed off the points or grains which originally covered its surface. Like *S. mucronata* it varies greatly in the length of its hinge, which sometimes runs out to two points.*

Spirifera ziczac is a rather fat looking small shell with 16 to 20 rounded ribs, crossed by prominent edges of the growth-plates in such a way as to give the whole surface the aspect of having been sculptured to a zigzag pattern; the middle fold of the upper valve double; that of the lower valve deep, and lifted in front. It seems to be confined in New York State to the Moscow shale.—*Spirifera sculptilis* a little like *S. ziczac*, has only 8 large prominent ribs crossed in zigzag by strong high growth-plate edges, looking as if they had been grooved out with a tool; the middle ridge of the upper valve is scarcely larger than one of the ribs. Apparently confined in New York to the Encrinal limestone underneath the Moscow shale.

Spirifera fimbriata a thin shell, commonly only found as a cast (see Hall's Fig. 10a, p. 208, upper valve). The lower valve is nearly circular with 12 rounded ribs, crossed by lines of growth which are *fringed* (fimbriated). This shell began in *Oriskany* and lived on through Corniferous into Hamilton times.

Atrypa (*Terebratula*) *reticularis* (*prisca*, *affinis*) is a

* Hall's figures on p. 207, show a larger shell (front, side and end view) *not* distorted; and a smaller specimen, with numerous, sharp, concentric growth-lines.—*Spirifera congesta* resembles the last when flattened; but when the pressure has been sideways it has a very fat look. Its middle fold is plain, its surface free from granulations; its ribs are fewer.


CLXIV
No. VIII c, Hamilton fossils. J. Hall 1891.
Newberria claypolii in Perry Co.
N johannis, Hall.
N. (Rensselæria) missouriensis, Sw.
Newberria (Rensselæria) lævis, Meek (not R. lævis, Hall)

fossil shell of various sizes; often flattened by pressure; abundant, widely distributed throughout the Hamilton and Chemung strata, but more abundant (in W. New York) at the top of the Ludlowville shales, in company with *Sp. mucronata*, and *Athyris spiriferoides* (*Atrypa concentrica*); but also abundant in the *Moscow shales*.

Atrypa aspera (*spinosa*) is often mistaken for *Atrypa reticularis;* but it may be distinguished by its spiny shell. The spines however are commonly rubbed off partially or entirely, and then it resembles the English *Atrypa squamosa.**

Athyris spiriferoides (*Atrypa* † *concentrica*), so called because looking like a Spirifer, is a very abundant fat roundish shell, bent in at the middle toward the edge; the two beaks closely pressed together; shell scratched with a great number of fine concentric semicircular lines of growth, which in young specimens project their edges so as to make the whole shell look scaly. A general smoothness and absence of radiating ribs, grooves or scratches, marks this shell. In New York it is exceeding abundant, especially in the top beds of the Ludlowville shale; but it occurs also in the Moscow shale.

Nucleospira (*Atrypa*) *concinna* of the Moscow shale is a nearly smooth little shell, with one elavated line of growth near the beak, and one or two near the margin; an

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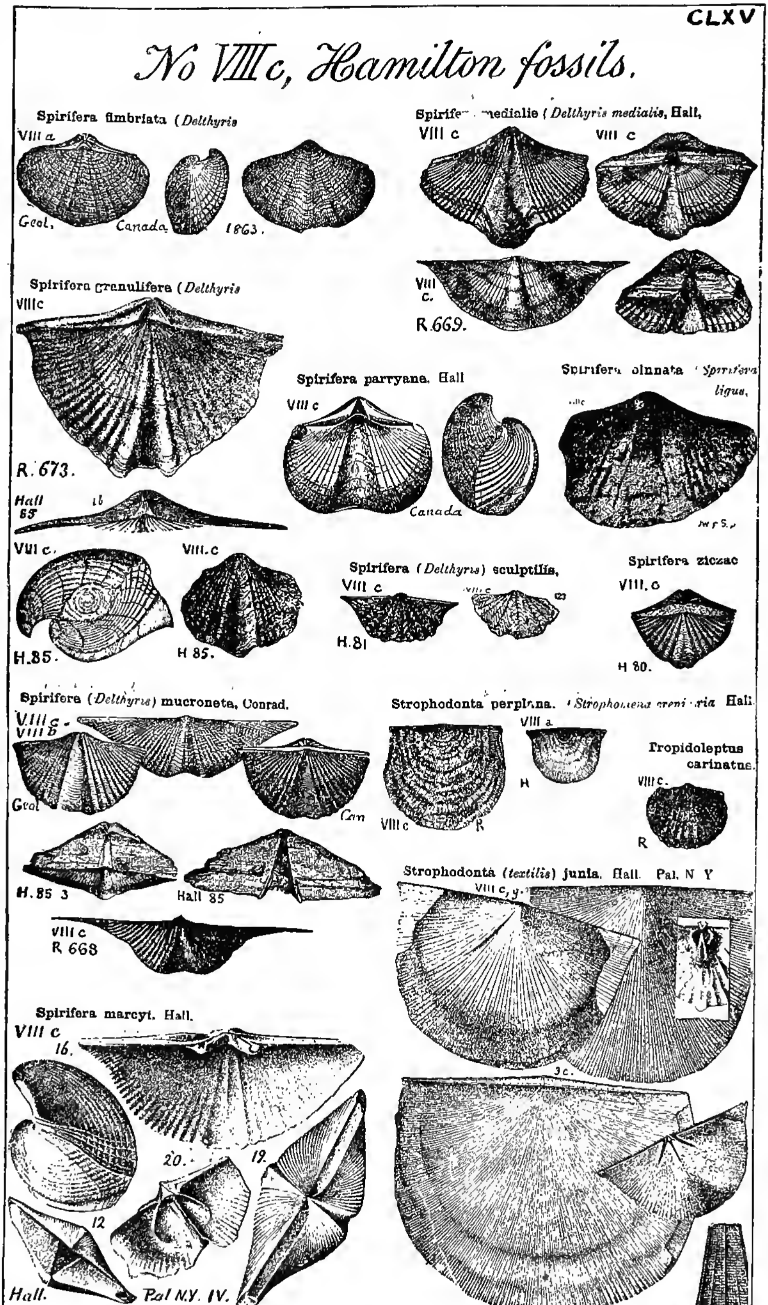
* When distorted by pressure the ends of the hinge are sharpened; lower valve, beak low; about 20 rays, often bifurcating very regularly at about half way from beak to base, as if the animal adopted suddenly a new theory of construction. Rays crossed by many concentric growth plate edges, each folded upon each ray and sticking out as a little spine, $\frac{1}{4}$ to $\frac{1}{2}$ inch. The projecting edges of the growth plates are striated concentrically as if each growth plate was itself made up of many thin subordinate growth plates. (Fig. 1b).

† *Atrypa* means *no hole* in the beak; but of the more than a hundred species originally called on this account *Atrypa*, all but 20 have been found to have a small hole concealed under the long and incurved beak, and have therefore been removed to the genera *Leptocœllia*, *Rhynchonella*, *Camarella*, *Pentamerella*, *Coelospira*, *Zygospira*, *Trematospira*, *Nucleospira*, *Stenoschisma*, *Eichwaldia*, *Terebratula*, *Meristella*, *Rensselaeria*, *Anastrophia*, *Leiorhynchus*, *Eatonia*, *Merista*, *Meristella*, *Meristina*, *Orthis* and *Athyris*, to one or other of which, for one or other reason they more properly belong (see S. A. Miller's list in American Palæozoic Fossils, Cincinnati, 1877).


CLXV
No VIIIc, Hamilton fossils.
Spirifera fimbriata (Delthyris
VIII a
Geol, Canada 1863.
Spirifera medialis (Delthyris medialis, Hall,
VIII c
VIII c
VIII c.
R.669.
Spirifera granulifera (Delthyris
VIIIc
R.673.
Hall 85
Spirifera parryana, Hall
VIII c
Canada
VIII c.
VIII.c
H.85.
H 85.
Spirifera (Delthyris) sculptilis,
VIII c
H.81
Spirifera ziczac
VIII.c
H 80.
Spirifera (Delthyris) mucronata, Conrad.
Geol
Can
H.85 3
Hall 85
VIII c
R 668
Strophodonta perplana.
VIII a
H
VIII c
R
Tropidoleptus carinatus.
VIII c.
R
Strophodonta (textilis) junia, Hall. Pal. N Y
VIII c, 9.
3c.
Spirifera marcyi, Hall.
VIII c
16.
20.
19.
12
Hall.
Pal N.Y. IV.

indistinct line on its round lower valve from beak to base; small beaks close pressed together; lower beak small; sharp, and incurved.

Strophodonta (*Strophomena*) *inæquistriata* * of the Moscow shale is a beautiful semicircular shell with sharp points at the ends of its hinge line, and radiating striæ from its beak to its margin, every fourth or fifth one more prominent than the rest, (whence its name), increasing in number as they diverge; upper valve flattish; lower valve very round.†

Meristella (Atrypa) *rostrata* of the *Encrinal limestone* is a neat little shell with a disproportionate big beak (whence its name); with a few growth lines; its lower valve with a middle groove from beak to margin.‡

Discina (*Orbicula*) *grandis* in middle New York is a common shell exclusively confined to the *Hamilton* rocks; is sometimes seen in the western district; has a nearly *flat circular* upper valve, indented on its under side (inside or cast) like the human navel, with a slight groove running to the margin (see fig. from Vanuxem, p. 152, f.4); lower valve shaped like a cap.

Of the *Gasteropods*, the following whorled shells are given by Hall in his first report of 1843, and therefore must be considered those most frequently presented along the New York outcrop.

Pleurotomaria (*Turbo*) *lineata*, generally preserved only as a *cast* of the inside, is abundant in some localities, frequently overgrown by a coral. The outside surface when preserved is marked by several sharp spiral lines, only the central one of which is seen on the surface of the cast.

Loxonema (*Terebra*) *nexilis* a more slender whorled shell than the last, is an English species; the whorls being

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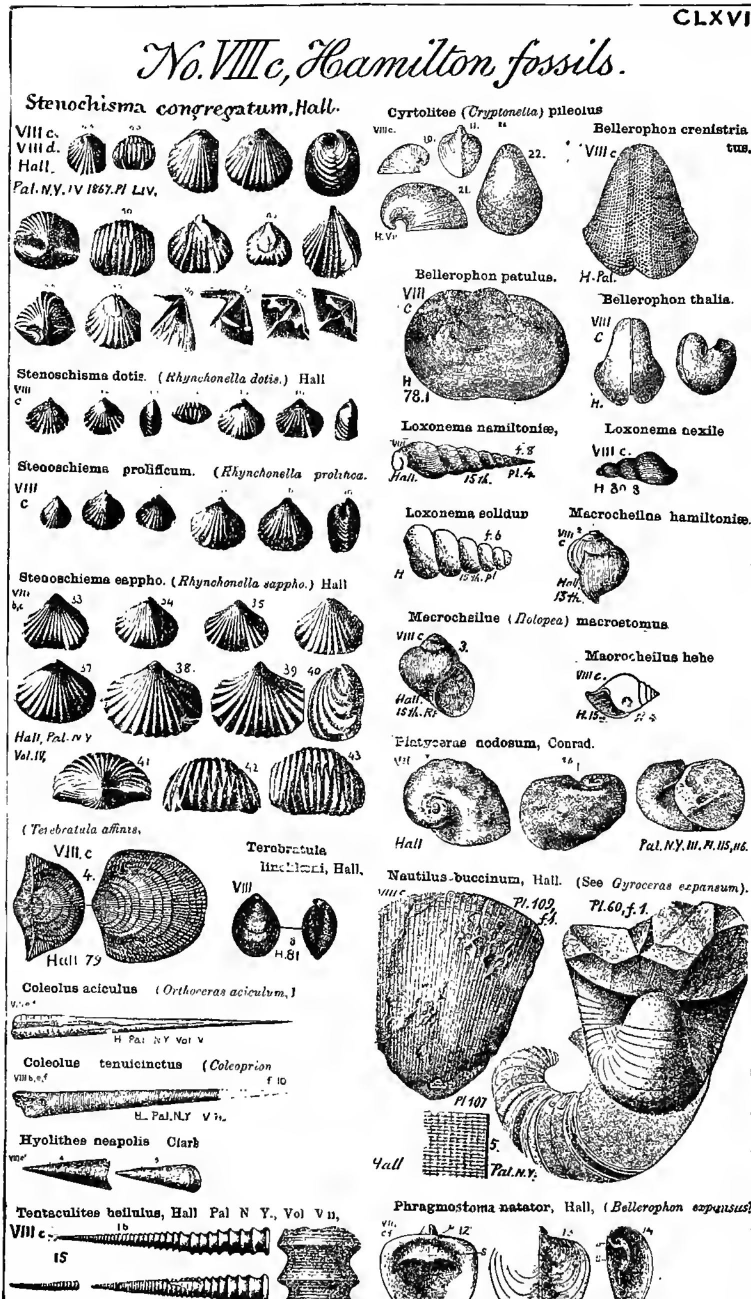
* Possibly the same as *Strophodenta* (*Strophomena*) *mucronata*, and the English *Orthis interstialis* (Hall, 1843 p. 201).

† This shell lived on into Chemung times; but the specimens found in the Chemung are usually compressed; have sharper striæ; and the shell matter is partially or entirely gone.

‡ Another similar but larger shell and two other Atrypa-like shells, one larger and the other smaller even than the *M. rostrata*, are figured by Hall as specially confined to the *Encrinal limestone* (1843, p. 202).


CLXVI
No. VIII c, Hamilton fossils.
Stenochisma congregatum, Hall.
VIII c.
VIII d.
Hall.
Pal. N.Y. IV 1867. Pl LIV.
Stenoschisma dotis. (Rhynchonella dotis.) Hall
Stenoschisma prolificum. (Rhynchonella prolifica.
Stenoschisma sappho. (Rhynchonella sappho.) Hall
Hall, Pal. N.Y. Vol. IV.
(Terebratula affinis.
VIII. c
Hall 79
Terebratula lincklaeni, Hall.
H. 81
Coleolus aciculus (Orthoceras aciculum.)
H Pal N Y Vol V
Coleolus tenuicinctus (Coleoprion
H. Pal. N.Y. V
Hyolithes neapolis Clark
Tentaculites bellulus, Hall Pal N Y., Vol V II,
VIII c.
Cyrtolites (Cryptonella) pileolus
Bellerophon crenistriatus.
VIII c
H-Pal.
Bellerophon patulus.
VIII c
H 78.1
Bellerophon thalia.
VIII C
H.
Loxonema hamiltoniae,
Hall. 15th. Pl. 4.
Loxonema nexile
VIII c.
H 80 8
Loxonema solidum
H 15th. Pl
Macrocheilus hamiltoniae.
Hall 15th.
Macrocheilus (Holopea) macrostomus
VIII c 3.
Hall. 15th. Rf
Macrocheilus hebe
VIII c.
Platyceras nodosum, Conrad.
Hall
Pal. N.Y. III. Pl. 115, 116.
Nautilus buccinum, Hall. (See Gyroceras expansum).
Pl. 109, f. 1.
Pl. 60, f. 1.
Pl 107
5.
Hall
Pal. N.Y.
Phragmostoma natator, Hall, (Bellerophon expansus?
12
15 th.
6

crossed in a peculiar curved manner by alternate ribs and furrows.*

Bellerophon patulus, a gasteropod shell coiled like a *Nautilus*, only that its mouth suddenly spreads out like a French horn.

Nautilus (*Phragmoceras*, *Cyrtoceras*) *maximus* the largest coiled chambered shell found in Palæozoic formations, was found by the N. Y. geologists at Lewis' quarry (for the Shenango canal) near Solsville, where the greatest number and best preserved specimens of it exist.†

Of *Cephalopod shells* (cuttle-fish) *Orthoceras constrictum* is peculiar to the *Hamilton formation* in middle New York, a "straight horn" with a deep crease around it near its mouth, like that made by aborigines around a stone hammer to receive a twisted thong for a handle.

Of *Lamellibranch shells* the Hamilton formation has the greatest abundance of genera, species and individuals, a few of which deserve special mention because they characterize its outcrops in Pennsylvania as well as in New York.‡

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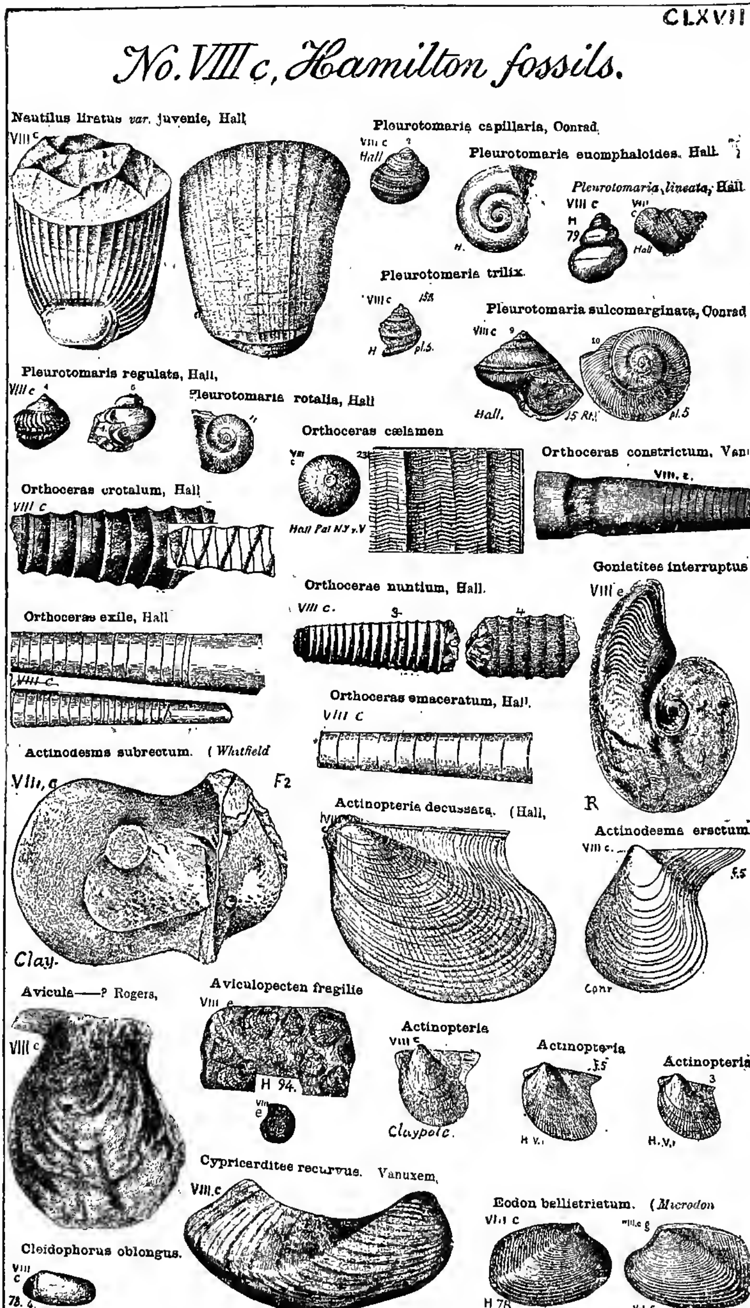
*One of these shells is figured by Prof. Hall in his description of the *septaria* or nodules of iron pyrites, which often embrace a fossil, as showing the first stages of the growth of the mineral around the dead shell (1843, p. 193, Fig. 76).

† Vanuxem, 1842, p. 159 (see Mather's plate 19). This quarry is rich in *Goniatites punctatus*, *Conularia*, *Aviculoid shells*, *Mytilurca triquetra*, *Cypricardites alveatus*, *Discina* (*Orbicula*) *grandis*, etc., etc.

‡ I extract the following Hamilton lamellibranches from Prof. Hall's Ms. list distributed in 1886 (with printed catalogue) to illustrate his Vol. V, par-I, Palæontology of New York :—Actinopecten boydii, decussata, subdecus, sata ;—Aviculopecten princeps, scabridus, exactus, fasciculatus, idas, lautus, bellus, ornatus, mucronatus ;—Cemetarea corrugata, elongata, recurva ;—Cypricardinia indenta ;—Glyptodesma erectum ;—Goniophora hamiltonensis, rugosa, truncata, glaucas ;—Gosseletia triqueter ;—Grammysia bisulcata, nodocostata, magna, circularis, obsoleta, bellatula, alveata, globosa, arcuata, constricta, (Sphenomya) cuneata ;—Leda diversa, rostellata ;—Leiopteria conradi, greeni, rafinesqui, sayi, dekayi, bigsbyi, gabbi ;—Lemopteria macoptera ;—Leptodesma rogersi (the remaining 40 species of this genus being all Chemung forms) ;—Lunulicardium curtum ;—Lyriopecten orbiculatus ;—Macrodon hamiltoniæ ;—Microdon bellistriatus, gregarius (also Chemung), tenuistriatus, complanatus ;—Modiella pygmæa ;—Modiomorpha concentrica, mytiloides, alta, macilenta, subalata ;—Mytilarca (Ptethomytilis) oviformis ;— Nyassa arguta, subalata, recta :—Nucula randalli, lirata, bellistriata, varicosa, corbuliformis, lamellata ;—Nuculites oblongatus, cuneiformis,


CLXVII
No. VIII c, Hamilton fossils.
Nautilus liratus var. juvenis, Hall
VIII c
Pleurotomaria capillaria, Conrad.
VIII c
Hall
Pleurotomaria euomphaloides. Hall.
Pleurotomaria lineata, Hall
VIII c
H
79
Hall
Pleurotomaria trilix.
VIII c
H
pl.5.
Pleurotomaria sulcomarginata, Conrad
VIII c
Hall.
pl.5
Pleurotomaria regulata, Hall,
VIII c
Pleurotomaria rotalis, Hall
Orthoceras cœlamen
Hall Pal N.Y. v.V
Orthoceras constrictum, Van
Orthoceras crotalum, Hall
VIII c
Goniatites interruptus
VIII c
Orthoceras nuntium, Hall.
VIII c.
Orthoceras exile, Hall
VIII c
Orthoceras emaceratum, Hall.
VIII c
Actinodesma subrectum. (Whitfield
VIII, c
F2
R
Actinopteria decussata. (Hall,
Actinodesma erectum
VIII c.
Clay.
Conr
Avicula——? Rogers,
VIII c
Aviculopecten fragilis
VIII c
H 94.
Actinopteria
VIII c
Claypole.
Actinopteria
H V.
Actinopteria
H.V.
Cypricardites recurvus. Vanuxem,
VIII.c
Eodon bellistriatum. (Microdon
VIII c
H 78
Vol.5
Cleidophorus oblongus.
VIII
c
78. 4.

Modiola concentrica abounds in the coarser shales in eastern and middle New York. This oblong shell, 2 inches long, with a curved hinge at one end, is covered with regular equal concentric growth lines, crowded together at the margin; its beak looking as if soldered on to the side of its end. It resembles the English *M. semisulcata.*

Eodon (*Microdon*) *bellistriata*, a beautifully marked and easily recognised shell, 1¼ inches long, is abundant in many parts of the eastern and middle sandy shale outcrop, but exceedingly rare towards Lake Erie. It is common in Pennsylvania and through Virginia; and its young specimens resemble the English *Venus parallela*, Phillips. It is marked by numerous equal concentric striæ; and the margin which is furthest from the hinge looks as if it had been worn or ground off square.

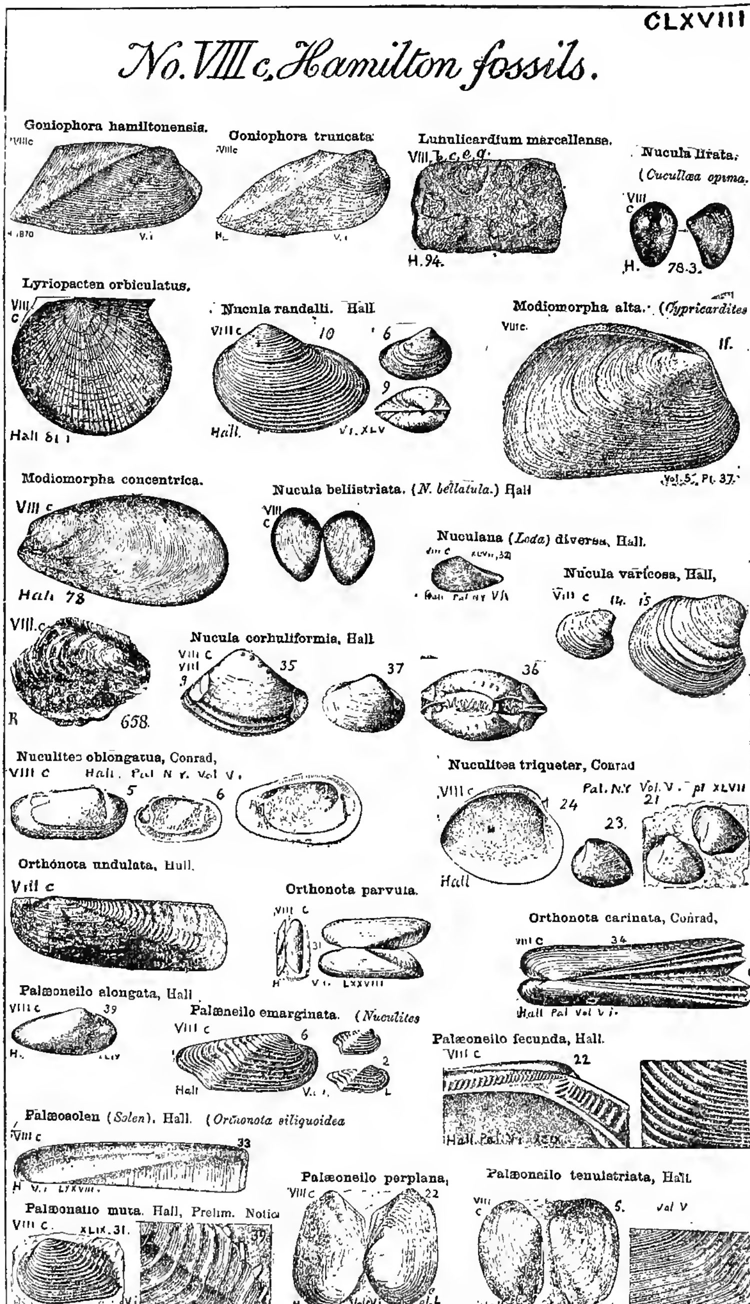
Cleidophorus (*Nucula*) *oblongus* is very common on the little lakes and in the Genesee valley country. It is only ¾ inch long, oblong, elliptical, the hinge very much towards one end, very finely and concentrically striated, with an impressed line extending from the hinge just forward of the beak half-way to the base.

Tellinomya (*Nucula*) *lineata*, Phillips, an English fossil, with a triangular look (on account of the great height of its beaks), and its surface covered with coarse concentric striæ, *is not very uncommon* in the Seneca and Cayuga ravines, but is usually distorted by pressure.

Nucula bellistriata, a beautiful little shell with a surface covered with regular fine concentric striæ, the hind slope of it slightly depressed along a belt which gives it a bent-in look, and its hinge margin set with distinct little teeth, is often seen in the harder shales on lakes Seneca and Cayuga.

Nucula (*Cucullea*) *opima* is a fat little shell, with promi-

triqueter;—Orthonota carinata, parvula?, undulata;—Palæoneilo brevis (also Chemung), constricta, emarginata, fecunda, maxima, muta, planat perplana, tenuistriata;—Paneuka radians;—Paracyclas lirata, tenuis;—Phol adella radiata;—Phthonia cylindrica, sectifrons;—Prothyris lanceolata;—Pterinea flabella (also Chemung);—Pterinopecten conspectus, hermes, intermedius, nodosus, vertumnus;—Schizodus appressus;—Sphenotus arcæformis, cuneatus, solenoides, truncatus:—Tellinopsis subemarginata.


CLXVIII
No. VIII c. Hamilton fossils.
Goniophora hamiltonensis.
Goniophora truncata.
Lunulicardium marcellense.
Nucula lirata.
(Cucullæa opima.
Lyriopacten orbiculatus.
Nucula randalli. Hall
Modiomorpha alta. (Cypricardites
Modiomorpha concentrica.
Nucula bellistriata. (N. bellatula.) Hall
Nuculana (Leda) diversa, Hall.
Nucula varicosa, Hall,
Nucula corbuliformis, Hall
Nuculites oblongatus, Conrad,
Nuculites triqueter, Conrad
Orthonota undulata, Hall.
Orthonota parvula.
Orthonota carinata, Conrad,
Palæoneilo elongata, Hall
Palæneilo emarginata. (Nuculites
Palæoneilo fecunda, Hall.
Palæosolen (Solen). Hall. (Orthonota siliquoidea
Palæoneilo perplana,
Palæoneilo tenuistriata, Hall.
Palæoneilo muta. Hall, Prelim. Notice

nent beaks near the front end, and its outside surface covered with coarse concentric lines ; the inside of the shell, as shown by the surface of internal casts, is nearly smooth.

Sanguinolites (*Cypricardia*) *truncatus* is a queer little shell which seems to have been cut into a kind of pyramid (trapezoid) with a knife. Its surface is covered with concentric wrinkles which run nearly at right angles to those on the side of the shell ; its hind slope elevated like a boat's keel ; resembles the English *Cucullea arguta*, Phillips.

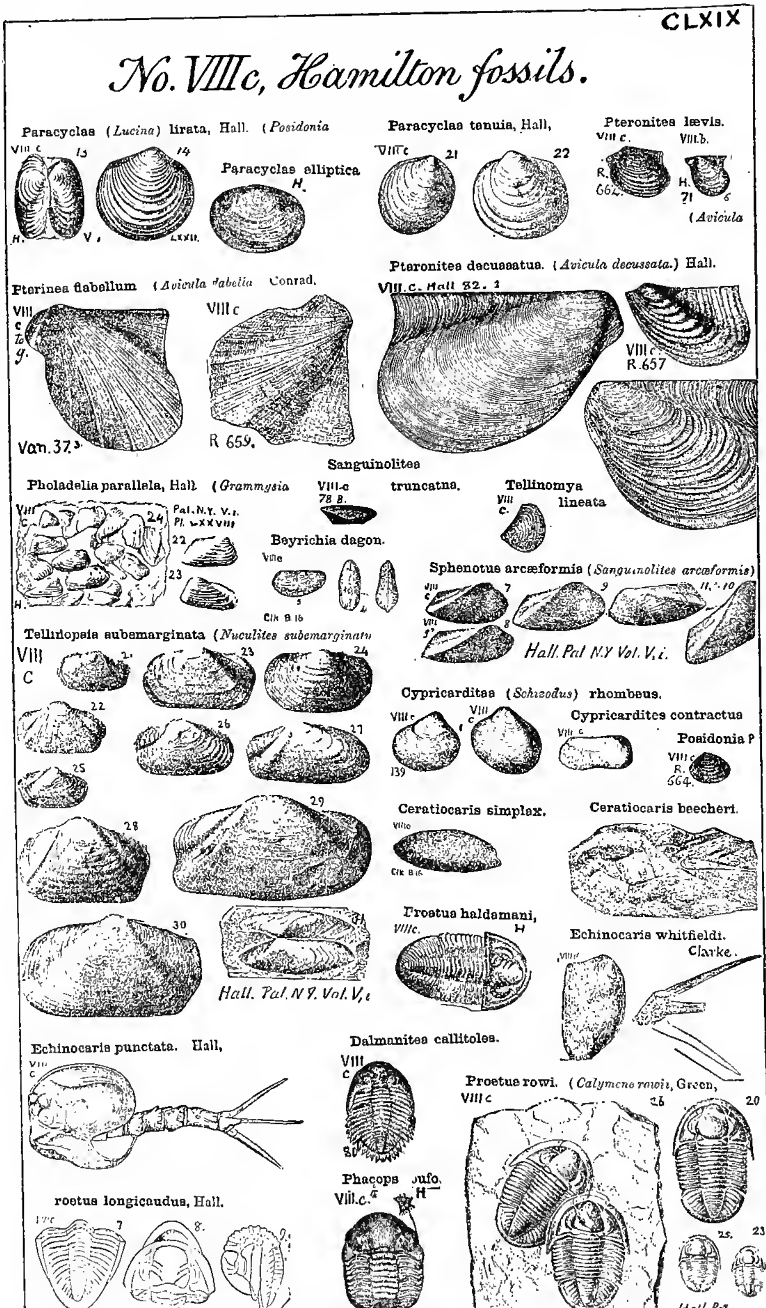
Palæoneilo maxima (*Tellina ovata*), a smooth ovate shell, 1¼ inches long, with a surface covered by minute concentric striæ, which become prominent near the margin.

Lyriopecten (*Avicula*) *orbiculatus*, is a scollop shell, 1¾ inches broad, *nearly round*, with a slightly slanting hinge line projecting in ears at the ends ; surface covered with radiating ribs, crossed by less prominent concentric growth-plate edges. It is one of the special Encrinal limestone fossils, and although not abundant is nevertheless found along the whole Hamilton outcrop of middle New York.

Pteronites (*Avicula*) *decussatus* is a special *Encrinal limestone fossil* throughout western New York, found in the lime-shales. Its outer surface is marked by fine radiating lines which only run from one growth-plate edge to the next; and these growth-plate edges are irregularly concentric, more like wrinkles, and stronger than the rays. The cast of the *inside* shows no rays (see Hall's Fig. 2, 1843, p. 203).

Pterinea (*Avicula*) *flabellum* is exceedingly numerous in middle New York and confined to the *Hamilton* ; is seen in western New York but not considered typical of its formation there. Its well marked shape, seven or eight large ribs, and fine intermediate ones, make it unmistakable among the fifteen or twenty Aviculoid species of the formation, such as :—*Aviculopecten* (*Avicula*) *parilis* (*Monotis princeps*) which is a common form ; and—*Actinodesma* (*Avicula*) *erecta*, also a common one, and confined to the *Hamilton formation.*

Orthonota undulata, a straight shell, more than 2 inches



CLXIX
No. VIIIc, Hamilton fossils.
Paracyclas (Lucina) lirata, Hall. (Posidonia
Paracyclas elliptica
Paracyclas tenuis, Hall,
Pteronites lævis.
(Avicula
Pteronites decussatus. (Avicula decussata.) Hall.
Pterinea flabellum (Avicula flabella Conrad.
Van. 37.
R 659.
R. 657
Sanguinolites truncatus.
Pholadella parallela, Hall. (Grammysia
Tellinomya lineata
Beyrichia dagon.
Sphenotus arcæformis (Sanguinolites arcæformis)
Hall. Pal. N.Y. Vol. V.
Tellinopsis subemarginata (Nuculites subemarginata
Cypricardites (Schizodus) rhombeus.
Cypricardites contractus
Posidonia ?
Ceratiocaris simplex.
Ceratiocaris beecheri.
Proetus haldamani,
Echinocaris whitfieldi. Clarke.
Hall. Pal. N.Y. Vol. V.
Echinocaris punctata. Hall,
Dalmanites callitoles.
Proetus rowi. (Calymene rowii, Green,
Phacops bufo.
Proetus longicaudus, Hall.
Hall Pal

long, with the knob near one end, is a typical Hamilton species in eastern, and not uncommon in middle New York, but wholly unknown west of the Genesee river.

Cypricardites recurvus. This very singular looking shell, 3 inches long, is found in the *Hamilton formation* only in eastern New York, but is not considered typical of it in western New York.

Of three *Trilobites*, two are peculiar to the *Hamilton* in New York; and all three have been repeatedly seen in its Pennsylvania outcrops.

Phacops bufo (*Calymene bufo*) meaning "the lens-eyed toad," with its large middle head-lobe covered with pimples, its 10 body joints and 8 tail joints, is one of the most abundant of *Hamilton* fossils, being found, either perfect or in fragments, at almost every locality.

Dalmanites (*Cryphæus*) *calliteles* "the handsome tailed" *Dalmania* of Barrande's Bohemian list, with its moon-shaped head-piece, wrinkled in the middle, and its cheeks pointing down to the fifth joint of the body; 10 body-joints; 10 middle and 6 side nail-joints; with their pointed ends projecting from the animal's sides, giving it a beautiful toothed fringe all around; head and eyes like those of an *Asaphus;* surface pimpled or (by the loss of the pimples) pitted.

Homalonotus (*Dipleura*) *dekayi* * is not peculiar to the Hamilton, for it ranges down through the Marcellus; and what seems to be its tail has been found as high as the Chemung. Heads and tails are usually found detached and separate abundantly in the sandy shales of middle and eastern New York; rarely in comparison in the softer shales of western New York.†

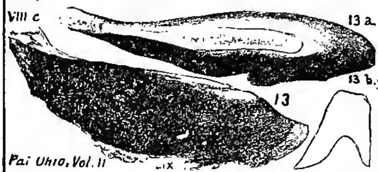
* Hamalos-notos, Greek, meaning, the head "on a level" with "the back."

† Vanuxem says that entire specimens are rare, but heads are plenty; they resemble those of the dolphin-headed trilobite *Trimerus* (*Homalonotus*) of the Clinton formation (No. V) or more closely the one in the *Niagara sandstone;* but the difference is considerable in the snout, and the parts about the eyes, being in the *Dipleura* more full or prominent. Murchison's *Homalonotus* differs only in that the tail has three lobes, the *Dipleura* only one. But in Ladd's quarry north of Sherbourne Vanuxem found two or three perfect trilobites with three lobed tails, and near them *Dipleura* of the same size (the largest not over an inch) with one lobed tails. So that there can be no doubt about the identity of the English and American species.

CLXX

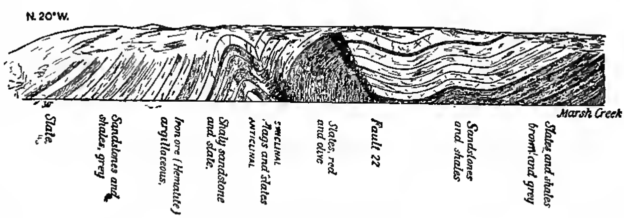
No. VIII c, Hamilton (Concluded.)

Ptychodus calceolus *'Rinodus' calceolus*, Newb.



Taonurus typus. (*Spirophyton typum*, Hall,

Downthrow fault in Hamilton rocks, No. VIII.
shown in Quarry 1½ miles W.N.W. of Eagleville, Centre Co., Pa.
sketched by E. V. D'Invilliers. (Looking S. 70° E.)

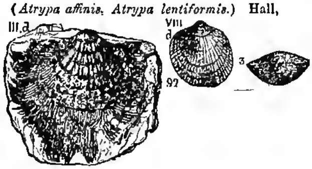


300 T.

Plate XII

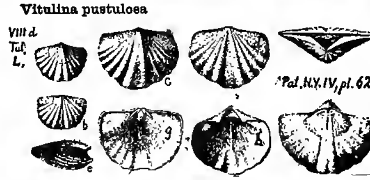
No. VIII d. Tully limestone fossils

(*Atrypa affinis. Atrypa lentiformis.*) Hall,



Orthis resupinata. (*Anomites*

Vitulina pustulosa



Rhynchonella venustula, Hall.

Fig. 94 (page 351) Section along the river bluffs above South Danville.

Special list of C. E. Hall, O3, p. 200.

On the Delaware at Marshall's Falls, Dingman's Falls, Walpack Bend and Port Jervis were collected for the cabinet the following species from various parts of the Hamilton shale and sandstone outcrop:—

Actinopteria boydii, subdecussata, Ambocælia gregaria, umbonata, Athyris angelica, spiriferoides, Atrypa reticularis, Aviculopecten princeps, Bellerophon leda (?), patulus, triliratus, Chonetes coronatus, laticosta, mucronatus, (numerous), scitula, Cimitaria recurva, Coleolus aciculus, Conocardium cuneus?, Crinoids, Cyathophyllum (obscure calyx), Dalmanites (Cryphæus) boothii (numerous), calliteles, ampla, media, and a species with both valves convex, Fenestella (both faces) numerous but too obscure to name, Fistulipora (obscure), Fish scale, Goniophora hamiltonensis, Grammysia (Sphenomya) cuneata, and another undetermined, Heliophyllum halli (cast of calyx), Hyolithes (the base of an individual), Homalonotus——? (very obscure), Lingula maida, Leiopteria dekayi (two), Lepidodendron gaspianum, Leptodesma robustum (?), Leptocoelia——? a rare form (two), Michelinea, Modiomorpha concentrica, Modiella pygmæa (twice with Nucula bella), Nautilus liratus, var. juvenis, Nuculites oblongata, Nucula bella, Nucleospira concinna, Orthoceras cælamen (two), conscriptum, ohioense, crotalum, Orthis leucosia, tioga, vanuxemi, Palæoneilo brevis, fecunda (?), plana, Paracyclas elliptica, lirata, Phacops rana (numerous), Pholadella parallela, Platyceras carinatum, cymbium, erectum, nodosum, Pleurotomaria, arata, sulcomarginata, Prœtus rowi, Pterinea flabella, Productella lachrymosa, Reptaria stolonifera, Rhynchonella (Leptocoelia ? 3 examples), Spirifera arenosa, disjuncta, fimbriata (numerous), granulifera, marcyi, medialis, mesocostalis (numerous), mucronata, sculptilis, Streptelasma——? Strictopora gilberti, Strophodonta concava, demissa, perplana (several), Strophodonta perplana var. nervosa (on the same slab as S. disjuncta), Strophomena woolworthana, Tæniopora exigua, Tellinopsis (Tellinomya) subemarginata (numerous), Tropidoleptus carinatus (several).

Claypole's lists in Perry county.

The Hamilton sandstone in Perry county yielded :*—Bellerophon leda, Cardiomorpha bellatula (?), Chonetes cornutus (?), Chonetes logani var. aurora, Leiopteria rafinesquii, Lingula ligea (?), Loxonema delphicola, terebra, Orthis penelope, Phacops rana, Pleurotomaria capillaria, Pteronites, Rhynchonella congregata, prolifera, Spirifera formosa (?), medialis, mucronata, and Tropidoleptus carinatus.

The Hamilton Upper Shales in Perry county yielded to Claypole's researches:—Actinocrinus eucharis, Actinopteria decussata, subdecussata, Ambocoelia umbonata, Ancyrocrinus bulbosus, Atrypa aspera, reticularis, spinosa, Aulopora tubæformis, Aviculopecten orbicularis, princeps, Bellerophon crenistriatus, leda, patulus, thalia, Beyrichia punctulifera, Chonetes aurora, coronatus, lepidus, mucronatus, setigerus, Coleolus aciculus, tenuicinctus, Crania hamiltoniæ, Cryptonella rectirostra, planirostra, Cypricardia indenta, Cyrtina hamiltonensis, Dalmanites boothii above the Fenestella bed, Discina media, minuta, seneca (?)' Eodon bellistriatus, tenuistriatus, Favosites arbuscula, Fenestella, Glyptodesma erectum, Goniotites——? Homalonotus dekayi, Heliophyllum halli, Leiopteria dekayi, Leiorhynchus multicostatum, Lichenella (?), Loxonema delphicola, Macrodon hamiltonense, Modiomorpha alta, complanata, concentrica, neglecta, Nautilus (Gyroceras) liratus, Nucula bellistriata, lirata, randalli, Nuculana (Leda) diversa, Nuculites oblongatus, triquetra, Orthis penelope, vanuxemi, Orthoceras nuntium, subulatum, Orthonota carinata, parvula, undulata, Palæoneilo constricta, elongata, emarginata, fecunda, filosa, maxima, muta, plana, tenuistriata, Paracyclas lirata, Phacops rana, Pholidops hamiltoniæ, Platyceras attenuatum, carinatum, symmetricum,

* A list of genera and species determined by Prof. Claypole in the whole Hamilton group (Marcellus, Hamilton and Genesee) is given in the preface to Report F2, page xiii, a few figured by Rogers (1858) being added and marked *. All these are included in the subsequent pages and need not here be repeated, but they are grouped under the classes and families. Very few fossils are found in the 200′ of Barren shales. The underlying Paracyclas bed has a copious list of species differing widely from those at the top of the series of beds.

Pleurotomaria capillaria, sulcomarginata, trilix, Polypora fragments, Productella spinulicosta, truncata, Prœtus haldemani, macrocephalus, Ptilophyton vanuxemi, Rhynchonella contracta, hosfordi, prolifera, Sanguinolites truncatus, Spirifera acuminata, fimbriata, granulifera, medialis, mucronata, zigzag, Spirorbis angulatus, Spirophyton (Taonurus) velum, Streptelasma rectum, ungula, Streptorhynchus chemungense var. perversum, var. arctostriatum, Stictopora, Strophomena inæquistriatum, Strophodonta concava, inæquistriata, perplana, textilis, Styliola fissurella, Tæniopora exigua, hamiltonensis, undata, Tentaculites attenuatus, gracilistriatus, Terebratula lincklæni, Tropidoleptus carinatus, Vitulina pustulosa (below the Fenestella bed).

The Hamilton upper fossil ore bed in Perry county furnished :—Actinodesma subrectum, Ancyrocrinus bulbosus, Atrypa aspera, Chonetes coronatus, Eodon bellistriatus, Homalonotus dekayi, a large Orthoceras, a Productus, Rhynchonella congregata, Spirifera acuminata, medialis, and mucronata, Tentaculites attenuatus and Tropidoleptus carinatus.

White's lists in Huntingdon county.

The Hamilton Upper Shales in Huntingdon county gave White :—Athyris spiriferoides, Cardiomorpha bellatula, Chonetes coronatus, setigerus, Cypricardinia indenta, Crinoid plates, Dalmanites boothii, Homalonotus dekayi, Leiopteria bigsbyi, rafinesquii, Nuculites oblongatus, an Orthoceras, Orthonota undulata, Palæoneilo constricta, Phacops rana, Spirifera fimbriata, mucronata, granulifera, Tropidoleptus carinatus.

The Hamilton Lower Shales gave White in Huntingdon Co. :—Ambocælia umbonata, Leiorhynchus limitare, Pteronites lœvis, and Rhynchonella hosfordi.

Collections at Orbisonia in Huntingdon county, gave :—Chonetes scitula (numerous), coronata, and syrtalis ; a Grammysia ; Pterinea flabella (numerous); Pholidops arenaria (?) ; Spirifera disjuncta, granulifera, and mesocostalis ; Tentaculites spiculus (five large slabs covered with them); Terataspis grandis (two imperfect impressions of this trilobite verified by James Hall); Tropidoleptus carinatus; and the tracks of worms.

Collections at Bell's Mills in Blair county gave:—Atrypa reticularis, Athyris spiriferoides, Ambocoelia præumbona, Chonetes coronatus, Crinoid discs, Cyathophylloid fragments, Fenestella planiramata (?) and other species undeterminable, Goniophora hamiltonensis (both valves vertically compressed), Heliophyllum halli, Orthoceras nuntium, Pentamerella micula, Phacops rana, Spirifera mucronata, Stictopora subcarinata, gilberti, Strophodonta perplana, Terebratula harmonia, and Tropidoleptus carinatus.

CHAPTER LXXXX.

VIII d, Tully Limestone in New York.

The *Tully limestone* took its name from the village in Onondaga county, New York, where it is better developed (in that state) than elsewhere, and better marked by its peculiar fossils. It has not been seen more than thirty miles east of that point. Its outcrop may be followed seventy miles further westward, that is to the Genesee river one hundred miles in all.*

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* The *Tully limestone* on its New York outcrop is first seen in Smyrna, Chenango county, 8 miles west of Sherburne, on the turnpike, in four exposed layers.—Again 2 miles N. W. of DeKeyter, where it is quarried. Also 6 miles N. of DeKeyter.—Further west at *Tinker's falls*, 50′ high, the Tully is 12′ thick, projecting ten or fifteen feet beyond the underlying shales; upper layers good limestone, lower shaly.—At Tully Four-corners, 12′ thick; quarried; overlies "Moscow shale" (top of Hamilton); very rich in fossils.—On the Amber road, 20′ thick, quarry fifty feet above the road.—Surrounds the head of Otisco lake 300′ above water, dipping gently south, 15 thick, narrow terrace capped with *Genesee* slate. Smith's ledge; fossils not numerous; *Rhynchonella venustula* (*Atrypa cuboides*), *Atrypa reticularis* (*priscus*), etc.—Best of all its exposures at Ross' hill, N. E. part of Otisco township, Cayuga county; caps the highest land in four or five rock steps on the northern side; vertical joints drain it and make good wheat land.—Lake Skeneateles, east side, Hathaway's quarry, near Borodino, 150′ above lake; three thick and some thin layers, in all 14′.—West side, opposite Borodino, 1½ mile from lake; also Vanetten's mill on the road from Owasco to Kelloggsville.—Head of Owasco lake; underlies Montville, just above the mill dam, 100′ feet above the lake; makes *cascade* 70′ high.—Further south, a mile from Moravia, seven layers (second from bottom 5′) in all 16′ thick; cut through by Dry-fall creek, which has undermined it for 100′ feet, exhibiting its under surface.—Ascending to Stuart's corners, outcrop lighter than usual, *R. venustula* abundant.—Between Aurora and Ludlowville, extensively exposed.—Shows southward in all the ravines near the Thompkins county line, making numerous cascades.

Cayuga lake shore exhibits the Tully limestone for several miles. Between Bell's Ferry and Goodwin Point its lower surface is within a foot of the water; it rises southward to 35′ at Devil's Den and to 60′ at Ludlowville; then sinks and disappears beneath water level at Bloom's limekilns, half way between Salmon creek and the head of the lake (but the synclinal and anticlinal are only apparent, not real; the dip always remains southwest, but the lake shore curves); always black, blue, or brown; from 11′ to 18′ thick; one of the lower layers usual massive (often 5′), which makes

Northward rise of VIII d in New York.

The strikingly bold outcrop of the *Tully limestone* around the little lakes of New York and across the highlands which separate them offered too tempting an opportunity to be neglected for an instrumental survey to determine the rate of southerly dip of the Palæozoic strata towards Pennsylvania.*

In 1883 such a survey, undertaken by Prof. S. G. Williams of Cornell University at Ithaca, and published in American Journal of Science for October, 1883, pp. 303, was extended along the Tully outcrop through Yates, Seneca,

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caves under the falls. Often concretionary; roughly notched along the lines of bedding contact; sometimes fibrous, like the *Waterlime*. Blocks numerous on the lake shore below; some of vast size carried south by ice and stranded at various levels south and east of Ithaca, some several hundred feet above present lake level, proof of ancient submergence (Vanuxem's report of 1842, pp. 164-167).

Prof. Hall's long section (Report of 1844, Plate VII), shows two undalations on the east shore of Cayuga lake. He adds (Report, p. 213) that on the west shore there are three, the last one just south of Big stream point in Yates township, showing merely the top of the arch, but the whole of the formation with a few feet of *Hamilton shales* beneath it. Here the lower layers are concretionary, and in some parts mere ranges of lime balls in a matrix of shale; showing that at first there was not enough lime in the water to make real lime rock. Hall's woodcuts of the Cayuga lake outcrops on his pages 211, 214, are interesting.

Although the Tully is said to *underlie* the Genesee yet, at the mouth of Crooked lake where the Tully is 13′ thick, a thin stratum of Genesee underlies it.

Along the east side of Seneca lake the Tully limestone stands out high above the water like a shelf, being undermined by the waves of the prevalent west winds removing the Hamilton shales; the shore beneath being skirted with fallen blocks, mostly under water, because those on shore have been carted away for lime-burning; a dangerous practice, which facilitates the destruction of the cliffs. The occasional east winds have not much effect on the west side of the lake, and the outcrop is less visible.

The outcrop runs across the highland to the cascade at the outlet of Crooked lake, where it is seen sinking beneath the black *Genesee* slate.—West of this it is seldom seen. At Bethel it shows in Flint creek. At Bellona in a bed of a small stream where only 4′ thick it yields more fossils than anywhere else. On Canandaigua lake it is only *a few inches thick*. Lying as usual between *grey Hamilton under shales and black Genesee overshales*, this strong contrast enables the geologists to find it as a thin plate of hard impure limestone where it would otherwise be overlooked.

*The *Olean conglomerate* at the base of the *coal measures* has been used for the same purpose in northwestern Pennsylvania (Q4, pp. 1, 2, 3, 4).

Thompson, Cayuga, Cortland, Onondaga and Madison counties for 80 miles; the lake levels being referred to railroad grade, and the heights along the outcrop obtained by repeated aneroid barometer observations. Cayuga and Seneca lakes with the highland between them furnished the best data; Cayuga water level being established at 377′ A. T.; Seneca at 447′; highest point of outcrop (northward) between them, 739′; rate of dip from it to Little Point on west shore of Cayuga, S. 42° E. *36′ per mile;* to Lodi on east shore of Seneca (across three little synclinal basins) S 25° W. *37½′ per mile.*†

Description of Tully limestone in New York.

The special economical value of the Tully in New York depends on the fact that it is the highest or most southern limestone outcrop in that State; therefore farmers living

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*Along Cayuga lake (east shore) the Tully descends for 10½ miles (southward) past King's ferry to Lake ridge at a uniform rate of *42½′ per mile;* then lies nearly horizontal, about at water-level, but nowhere completely submerged, for three miles; then in the next six miles makes an arch, 235′ above the lake level, descending (S.) at *110′ per mile.*—On the west shore, opposite the horizontal stretch on the east shore, it is submerged for four and a half miles; rises at *65′ per mile;* makes an arch of four and a half miles span, to a height of 160′; and then sinks to the water at *80′ per mile.*—On Seneca lake, there are three synclinals two of which are slight. If the larger third (described in Prof. Hall's Report of 1843, page 212) be the synclinal on Cayuga lake, a line drawn from one to the other (N. 63° W.) and projected westward would cut the outlet of Crooked lake "near where the Tully has apparently suffered a fault of about 100′." But this is so opposed to the course of the synclinals of southern New York that it is safer to identify the Cayuga synclinal with the southernmost Seneca synclinal; or better yet to consider all the waves local and independant.—East of Cayuga lake on the highland a mile west of Scipio Station (on the west bank of Owasco lake) the Tully outcrop reaches a height of 1110′ A. T. From this (S. W.) to the bottom of the Cayuga synclinal, about seventeen miles, the rate of fall (S. W.) is *43′ per mile.* From the same point (S. E.) across Owasco lake, nine miles, to the last Tully exposure near the head of the lake (east side), the rate of fall (S. E.) is *34′ per mile.*

East of Owasco lake is Skeneateles lake. On the highland between them, on Pickett's hill (near Borodino, Fabius township, Onondaga county) the Tully outcrop is 1680′ A. T. From this point (S.) to Glen Haven at the head of Skeneateles lake, five and a half miles, the rate of fall (S.) is *38′ per mile;*—to a point one mile east of DeKeyter (Madison county) distance six and a half miles (S. E.) it is *40′ per mile;*—to a point near Cugler (Cortland county) distance six and a half miles (S. by W.) it is *56′ per mile.*

between its outcrop and the Pennsylvania State line, before the extension of railroads, resorted to it to stock their kilns, although it makes a dark but good lime.

In middle New York the formation consists of a set of layers of impure, often shaly, fine grained, dark, sometimes blackish, often brownish limestone, nowhere (in New York) more than 20′ thick; one of its lowest beds being commonly massive (5′); and its bottom layer occasionally concretionary, or even a layer of limeballs. It burns to a good, strong, dark lime. It contains iron and manganese; for, minute veins of carbonite of iron run through it; and the fossils of the rocks above (especially the encrinal stems and discs) are often replaced by the carbonates of iron and manganese (Vanuxem, 1842, p. 164).

In western New York the rock is usually thick bedded; but often divided by numerous irregular seams into small fragments. Sometimes it is in courses 6″ to 12″ thick, close grained and compact. Elsewhere its surface is completely checkered by seams; and in breaking the mass, the whole crumbles into small angular fragments, much in the same manner as the shales containing pyrites. It is often a lime-shale, the carbonate of lime in excess; often a pure limestone separated by thin shale parting into wedge-form and irregular laminæ. Blue, and often black in the quarry long exposure turns its surface to ash color. Its concretionary condition is not usual. It resists weathering better than the shales beneath and above it and therefore often projects from the face of a cliff.—It contains no valuable minerals. The cavities of fossils are often lined with *calc-spar*, and occasionally contain small crystals of sulphate of baryta (*barites*) (Hall, 1844, 212).

Along the western course of the New York outcrop fossils are as a general fact rare; further east more common; but the same species are found all along the line. At many places no whole shells can be found; all are broken up into fragments, and therefore probably drifted away from their original habitations.

The Tully identified as the Cuboides zone of Europe.

The most remarkable thing about the Tully limestone is that in middle New York, where it is thickest, it places no barrier to the upward extension of fossil species, from *Hamilton* to *Chemung;* whereas in western New York, where it is very thin, or entirely wanting, it serves as a fixed horizon separating the lower from the higher, i. e. the older from the newer forms of living creatures (Hall, 1843, p. 217).*

The *Devonian system* of Europe has been recognized in America by its fossils, by the color and general quality of some of its beds, but chiefly by its position in the vertical Palæozoic column between the *Silurian* system under it and the *Carboniferous* system over it.

At the first glance it was evident that the great grey series No. VIII (*Hamilton*, *Portage* and *Chemung*) must represent the South English Devonians, and that the great red series No. IX (*Catskill*) must represent the Scotch Old Red.

Prof. H. S. Williams, in a paper read at the Toronto meeting of the A. A. A. S. in 1889, relates his excursions among the Devonian rocks of England in 1888 (see A. J. Sc. Jan. 1890, page 31). He reviews the palæontology of all the known Devonian areas, and lays stress on a special zone of fossils, that of the *Rhynchonella cuboides.* "If we take this as a uniform horizon homotaxically (he says on p. 36) it may be said that a considerable number of species (including forms which under different names are closely allied modifications of the same races) appeared before the "cuboides" stage in the English, European and Russian sections, but not till after that stage in the New York sections." * * "The *acuminata* and *pugnus* types of *Rhynchonella* are known to us at the base of the east-

* At Ithaca, for example, the *Ithaca* formation is full of its own specialties, and yet among them are still found *Microdon* (*Eodon*) *bellistriatum*, *Modiomorpha* (*Modiola*) *concentrica*, and even *Phacops* (*Calymene*) *bufo*, and *Homalonotus* (*Dipleura*) *dekayi*. Still further east, where all the shales become sandy, there is a still greater mingling of upper and lower species.

ern *Chemung* terrace in Iowa at a doubtfully determined horizon, and in other western localities in association with *Carboniferous* faunas. In England and Europe they are conspicuous in association with what are called "Middle Devonian" faunas. *Spirifera disjuncta* is with them a Middle as well as Upper Devonian form. With us it is characteristic of the Upper Devonian fauna alone." * * * "There is a continuity in the succession from the lowest to the highest fauna of the [Devonian] system in Europe which we do not find in the American series." He regards the American and European faunas as different but allied up to the close of the *Hamilton* [*VIII b, c, d*]; but then, with the *Tully limestone* [*VIII c*] "an incursion of species of the European fauna began, and the following *Chemung* [*VIII g*] fauna shows a resemblance to the Upper Devonian of Europe," etc. The *Tully limestone* (*Cuboides zone*) abruptly stops the Hamilton fauna in the Central part of the Appalachian basin; but on the eastern side of the basin "the Hamilton appears to continue on, even mingling with the few Chemung species which appear on that side; while on the western side of the basin a distinct fauna, the *Waverly* (*Pocono, X*) succeeds the *Hamilton*, with no trace of the *Chemung* or '*Cuboides*' faunas between."

Characteristic Tully fossils.

Rhynchonella venustula (*Atrypa cuboides* of Sowerby) a peculiar little shell as round as a nut, with a flat lower valve, and a deep groove in the upper. was collected by Vanuxem from most of the exposures on the little lakes of New York, and by Hall at Bellona.*

Orthis tulliensis (*resupinata*, Phillips) is another shell which has never been seen in New York except in the Tully limestone. Its lower valve is very round. When its finely radiated surface is removed a multitude of minute pinpricks become visible.

For reduced figures of these two Tully fossils, see plate CLXX on page 1302 above.

* Hall's Report of 1843, p. 216. Sowerby's figure 24, Geol. Trans. Lond. vol. 5, pl. 56, and Philips' fig. 150, Pal. Foss. p. 84, pl. 34, give it 15 ribs; whereas the New York species has only 6 to 8.

Vitulina pustulosa is decribed by Hall (Pal. N. Y. Vol. IV, p. 410) as a Tully limestone species. A reduced copy of his figures will be found on the same plate CLXX.

Other fossil shells but not confined to the Tully, are abundant in its New York outcrops, some at one place, others elsewhere, viz: The Hamilton shell *Atrypa reticularis* (*lentiformis*, *affinis*) with its wonderful fringed edge (Hall, p. 215; Vanuxem, p. 163). A small Orthis also. *Strophomena linearis* (?) is in great abundance in the upper layers at Tully Four Corners; with a cup coral (*Cyathophyllum*) equally abundant at Bellona. Three species belonging to the Aymestry Limestone of England are rarer, viz: *Atrypa didyma*, *Avicula reticulata*, and the trilobite *Prœtus* (*Calymene*) *marginalis*.*

Area occupied by the Tully.

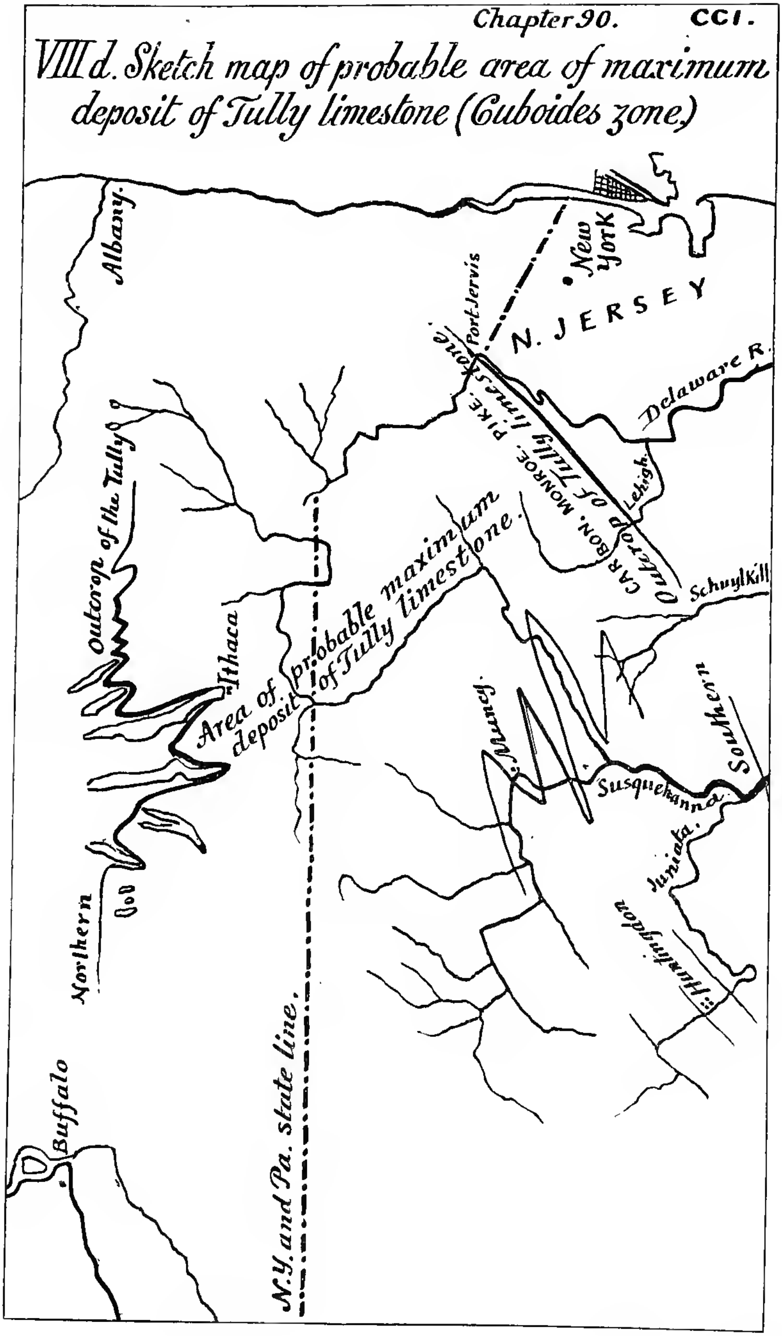
In eastern New York the *Tully* is wanting. From the Chenango river eastward a hundred miles to the valley of the Hudson, at Catskill, no *Tully limestone outcrop* can be found between the *Genesee* and *Hamilton* formations; it was not deposited in this part of the sea; nor has it been seen in southern New York as far as the Delaware river; but its outcrop begins again in Pike county on the eastern point of Pennsylvania and extends westward to the Lehigh river,† a distance of 60 miles. It evidently does not underlie the Catskill mountain country; nor can it have had an eastern origin. Neither can we seek its source in the west; for it is nowhere to be found in middle Pennsylvania west of the Susquehanna river.‡

From the head of Lake Cayuga in New York southeast to the Delaware river outcrop is a distance of 125 miles. Beneath this space the formation is concealed. No doubt it once extended much further north towards or into Canada,

*S. A. Miller does not recognize A. didyma, nor A. reticulata, as species of any American formation. Both Vanuxem and Conrad did.

†Where it seemed to be represented by a bed of corals, shells and crinoids, 50 rods north of Bowman's Station (G6, 109).

‡The only possible exception to this statement is the 5′ limestone in the Mapleton section, on the Juniata river in Huntingdon county (T3, 273).


Chapter 90.
CCI.
VIII d. Sketch map of probable area of maximum deposit of Tully limestone (Cuboides zone)
Albany.
New York
N. JERSEY
Port Jervis
Delaware R.
Outcrop of the Tully
Pike, Monroe, Carbon, Outcrop of Tully lime zone.
Lehigh
Schuylkill
Ithaca
Area of probable maximum deposit of Tully limestone.
Muncy
Susquehanna
Southern
Juniata
Huntingdon
Northern
Buffalo
N.Y. and Pa. state line.

and southeast towards the Atlantic ; but all we know of its past and present character over this really very large area we can only infer from its zigzag outcrops in Northumberland, Montour and Columbia counties between the North and West Branches of the Susquehanna river, 90 miles south of Lake Cayuga, and 50 miles west of the Delaware river. Here the formation is at its thickest (60′); and its lithological character the same as in New York.* But on the other hand all its fossils are of *Hamilton type ;* not a single peculier New York *Tully species* having been as yet observed in it. On the Delaware it is nowhere more than 30′ thick ; retains its character ; but holds no special Tully shells.

The Tully horizon.

The importance of these facts in their bearing upon our views of Palæozoic deposition can hardly be exaggerated. There is no mistake about the formation ; it is everywhere the same kind of sediment, immediately succeeding the bluish sandy shale deposits of *Hamilton* age ; immediately preceding the black mud deposits of *Genesee* age ; laid down under the same conditions, filled generally with the same kind of animal remains and apparently restricted to an area of great size indeed, but in reference to the whole Palæozoic water basin strictly local, rudely triangular, so far as our very limited knowledge of it extends, with very well defined limits in all directions except towards Lake Ontario northward and towards New Jersey southeastward ; and, so far from showing an increase of sediments in any direction, its thickest portion either lying transversely across the middle of the area, or located at its southwestern angle ; while its two or three special or characteristic shells lived only in the northern part of its area.

Were it not for the two peculiar shells in its New York outcrop, which had not previously lived in *Hamilton* times and were extirpated by the subsequent *Genesee* black mud deposits, the *Rhynchonella venustula*, and the *Orthis*

* Except that it is nowhere pure enough to burn into lime in competition with the Bossardville limestone (No. VI) always close by.

tulliensis, this *Tully limestone* would not have been made a separate formation from the *Hamilton ;* but would have been looked upon as merely the culmination and natural conclusion of liminess and populousness of the *Hamilton upper shales*, just previous to those physical changes in the sea currents which restored the *Marcellus* state of things, and made a second edition of nonfossiliferous black mud deposits in the shape of the *Genesee* formation.*

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*There is another reason for including the *Tully* in the *Hamilton* on the Delaware outcrop. Instead of lying between the *Genesee* and *Hamilton*, the *Coral bed* which represents the *Tully limestone* at the falls of Middle Bushkill creek in Pike county is overlaid by a set of hard dark sandstone beds, 15′ thick, which separate it from the *Genesee*, and shut it up in the *Hamilton* (see section in the previous chapter on *Hamilton on the Delaware*. Also G6, 213). On the other hand, in western New York Hall gives a section which shows *black slate between the Tully and the Hamilton.*—How often are we thus awakened by the warning voice of nature from our dreams of a fine discrimination and picturesque classification of the phenomena of time and space. Our knowledge of details is so poor that all our general statements are mere mutterings in sleep, or the incoherent rhapsodies of fever. The world is a kaleidescope ; at every touch it turns a little and the scheme of shapes and colors changes to our eye. Books and masters cannot save the student from a mental confusion which merely represents the infinite confusion of things. A malaria of the indefinitely complicated exhales from every region of geology and attacks the wise and simple alike. Happy the investigator whose intellectual constitution is not ruined by it in the end. Foolish generalizer, who mistakes the paroxyisms of chill and fever in his own incompetent imagination for an actual rythm in the energy of the world of which he dimly sees but the part of a part. Could we only lift what is left of our formations underground, one by one, like the leaves of a book, and scan the both lithological and palæontological map which covers it completely from one torn edge of it to the other, what a joy it would be to trace its numerous variations in their irregular, sinuous, branching or broken belts—mark where it thins and thickens or is wholly wanting; where its material is coarse or fine, sandy, limy, muddy ; and how its continuous or isolated colonies of shells of different species live, here in profuse commixture, there in special individual abundance. But all this is forever hidden from human sight; and the more a geologist studies outcrops, the surer he feels that his knowledge of formations scarcely surpasses in quantity or quality the information which a traveler brings back from China who has merely landed at Canton, Hong Kong, Shanghai and Pekin.

Lime water drips and streams from all limestone strata in the world in rills and brooks and rivers to the sea. Limestone ranges of mountain-land, like the Pyrenees, the Appenines, the Jura of Europe, limestone-plains like Lancaster county, the blue-grass country of Kentucky and the region west of the Mississippi river, limestone valleys like those which stretch along the Appalachian belt from Vermont to Alabama, are perpetually charging the ocean with a solution of carbonate of lime, from which whales, porpoises, seals and manatees construct their internal skeletons, shell-fish cover them-

The Tully in Eastern Pennsylvania.

Along the Delaware river, in Pike county, the *Tully limestone* is seen at the heads of the high cascades of the Sawkill, Rameyskill, Dingman's creek, and the Little Bushkill, where it is a perfect *mass of corals and shells* in a series of beds about 30′ thick.* A large number of genera and species are represented here: *Zaphrentis rafinesquii*, *Zaphrentis gigantea*, *Heliophyllum halli*; several species of *Syringopora*; and other forms not determined; in fact a regular *coral reef*. The matrix is a dark grey calcareous shale, penetrated in every direction by the corals, which when

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selves with little portable houses, and worlds of coral creatures build their rocky reefs. As without an infusion of carbonic acid in the atmosphere the surface of the continents would have remained always bare of vegetation, and there could have been no tree, no shrub, no moss, no bird, no beast—so, without a solution of carbonate of lime in the ocean, it never could have been inhabited by living things; for all wood and flesh is a compound of carbon, sulphur and hydrogen; and all bone and shell is a compound of carbon, phosphorus and lime. A special abundance of fossil shell and coral in any formation must therefore be accepted as a sure proof that the sea water at that time, or in that place was specially limy; and if a streak or belt of the formation is more crowded with such fossils than the rest ot it, we have a right to suspect that such streak or belt marks the geographical course ot some ancient current of lime water, issuing from the mouth of some river which at that time drained a limestone country, and tranversed the ocean in some fixed direction, whether or not we can discover the direction, or the causes which determined it.

But not necessarily in all cases a single great river. The lower current which issues from the Straits of Gibraltar is a resultant from the total of lime water flowing into the Mediterranean from the limestone mountains of Spain, France, Switzerland, Italy, Greece, Asia Minor, Palestine and Algeria, less the amount of liquid water evaporated from its surface, and the amount of solid carbonate of lime abstracted by its animal inhabitants.

The current flowing around the south end of Florida is the total of lime water poured into the Gulf of Mexico by the Mississippi and other rivers, less the liquid evaporated from its surface, and the solids abstracted by its living inhabitants. The Bahama banks shows what quantities of lime that current holds in solution; and the geographical distribution of the reefs indicate in a general way the coarse which the lime water has taken in its escape from the Gulf into the north Atlantic ocean.

* The relations of these strata to the cascades may be understood by referring to the preceding chapter on the *Hamilton formation on the Delaware* (G6, 198; 202; 212,213). At the Little Bushkill falls, the corals penetrate the dark bluish matrix in all directions; many have been dissolved out; the species are very numerous aud the individuals countless.

dissolved away from the weathered outcrops leave them *honeycombed*, spongy and rotten.

In Monroe county, on Brodhead's creek, north of Stroudsburg, and one and a half mile south of Spragueville, near Bonynge's, it is finely exposed in a roadside cutting.*

Near the Carbon county line it may be seen along the road at E. F. Kresge's, just south of Gilbert's P. O. † Also a mile north of Kresgeville. This is 45 miles from the Sawkill falls at Milford, beyond which eastward it has not been seen, but probably might be found in favorable situations, perhaps some distance into New York. Westward it has not been noticed, unless it be a bed in the Lehigh Valley RR. cut, 50 rods north of Bowman's station, Carbon county, in which *corals, shells and crinoids* are unusually abundant.

The Tully in middle Pennsylvania.

On the Susquehanna North Branch in Luzerne county the Montour anticlinal carries the arched outcrop of the Tully limestone underground a few miles east of where the axis crosses the river between the mouths of Big and Little Wapwallopen creeks ; but no exposures of it have been noticed either on its north or on its south dipping outcrop. On the river the *Genesee* (N. dipping) dark blue slates are exposed for 30′, and the *Marcellus* black slates for 25′ ; but there is a concealed space of 700′ which should hold the Tully (Section p. 197 G7).

Following its north dipping outcrop westward through Salem into Columbia county past Evansville and Fowlersville towards Lightstreet it is everwhere concealed under the drift-filled *Marcellus-Hamilton-Genesee* buried valley (G 7, 271).

Following its south dipping outcrop westward it is first seen in Nescopec township at the road forks just east of

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*A quarter of a mile south of the bridge over Brodhead's creek the rock is perforated in all directions. All that can be said here is that the *coral bed* is near the top of the *Hamilton* (G, 6,271.)

† At the eastern edge of Polk township. Here the coral bed is seen in the road, and is *supposed* to be the *Tully* because the *Genesee black slate* shows just south of it; but the contact is not visible (G 6, 305.)

Evans' mill, half a mile south of the river bank, where its dull gray and drab colored beds dip 40,° S. 10° E. (G 7, 200).—Next, in Mifflin township, Columbia Co. at the cross roads near Brown's mills on Ten Mile run, its impure ashen gray layers, showing a buff tinge on the weathered surface and dark blue in a fresh fracture, dip south beneath the dark blue-blackish sandy *Genesee* slates. (G 7, 277).—Next, in Maine, they are seen in the south bank of the river, dipping 40° (S. S. E.) under a steep slope of *Genesee* capped by *Chemung* (G 7, 282,283).

Along the river bank, here most of the rock cuts of the new North Branch railroad are in *Tully limestone* (very impure), 50′ (?) thick. At Bloomsburg ferry the *Tully* is 45′ thick (?); at Rupert, 50′ (?) dipping 40° (S. S. E.), dark blue, weathering buffish dull ashen-grey, some of its layers quite fossiliferous, but *no special Tully forms;* only the common *Hamilton* species: *Atrypa recticularis*, *Ambocœlia umbonata*, *Spirifera fimbriata* and *ziczac*, *Chonetes setigerus*, *Phacops rana*, a *Platyceras*, and others. Here the underlying *Hamilton upper shales* show *Atrypa recticularis*, *Spirifera mucronata*, and *granulifera*. But the overlying *Genesee* (white bleaching) blackslates seem to be non fossiliferous (G 7, 289).

South Danville is the only place where the exact thickness of the *Tully* has been got.* In the bluffs which here rise from the river bank to a height or two or three hundred feet, 300′ of *Genesee* dark non fossiliferous shales are perfectly exposed; under them 60′ of light dull grey (some dark blue) *Tully limestone*, also perfectly exposed by the descending road, dipping 65° to 70° (S.S.E.); and under it, at least 100′ of *Hamilton* dark olive sandy shales. None of the Tully beds are pure enough to burn for lime. They hold *Atrypa reticularis*, *Ambocœlia umbonata*, *Spirifera ziczac* and *fimbriata*, *Orthis vanuxemi*, *Chonetes setigerus*, a species of *Platyceras*, the two trilobites *Dalmanites calliteles*, *Phacops rana*, and a small coral *Zaphrentis*. In the top layers of the underlying Hamilton are *Spirifera*

* For the section which shows this fine exposure of the Tully see the bottom of plate CLXX, page 1302 above.

fimbriata and *granulifera*, and *Athyris spiriferoides* (G7, 351·2).

Further west, along this southern outcrop, the *Tully* is concealed until we reach Reed's school house, three or four miles from Northumberland. Here it is cut by the D. L. W. RR. holding *Atrypa reticularis*, *Strophomena rhomboidalis*, the two trilobites *Dalmanites colliteles* and *Phacops rana*, a coral *Zaphrentis*, and many *crinoidal* remains (G7, 339).

Crossing Montour ridge to the north-dipping outcrop in Hemlock township, Montour county, three miles north of Bloomsburg; the Fishing creek section shows 275′ of *Genesee*; 50′ (?) of Tully; 400′ of *Hamilton*. Here the impure fossiliferous bluish grey often slaty beds are seen weathering as usual to an ash color (with a buff tinge) holding Amboccelia umbonata, etc., and the two trilobites *Dalmanites calliteles* and *Phacops rana*, but no corals. By reference to the *Hamilton* lists of fossils at this locality in a previous chapter it will be seen that *Ambocoelia umbonata*, *Athyris spiriferoides*, etc., occur 50,′ 75′, 100′ and 250′ beneath the Tully limestone.

Going due west from this 10 miles to the next south-dipping outcrop of the Tully, we see exposed at the county line, a mile south of Chillisquaque creek, just north of Davis' road-forks, 20′ of shaly dark blue limestone, weathering ashen grey, and holding many *Ambocoelia umbonata*, *Dalmanites calliteles*, and other fossil fragments. The black *Genesee* is exposed a short distance above it (G7, 309, 310).—Following this outcrop five or six miles east north-east to Jerseytown in Madison township, Columbia county, the Tully is seen in the Danville road near G. W. Supplies, with the same weather surface and the same fossils as at an exposure next to be described; viz:—

North northwest from Bloomsburg, ten miles, at the head of the east branch of Chillisquaque creek, in Madison township Tully beds are seen making their last descent beneath the mountain land of north eastern Pennsylvania. They are well exposed at the roadside just north of C. Kramer's, apparently 30′ or 40′ thick; a dull grey blue limestone (weathering a yellowish ash grey), with plenty of *Ambocoelia umbonata*, *Spirifera ziczac*, *Atrypa reticularis*, and the two trilobites *Dalmanites calliteles* and *Phacops rana*, but no corals. The *Genesee* over them dip 12° to 15° (N.) for 200 yards along the road (G7, 207).

Supposed Tully outcrops west of the Susquehanna river.

In Huntington county Prof. White is disposed to recognize the Tully in a 5′ bed just under the Genesee black shale at Mapleton, at McConnellstown, and on the Patterson tract in Penn township, where only 2′ of it is visible. Nowhere are the special Tully fossils found.*

In Perry county, Prof. Claypole was late in establishing the Genesee 200′ thick because of an almost total absence of fossils in it except the characteristic Genesee form *Styliola fissurella* in the lower beds. But after establishing by characteristic species the highly fossiliferous Portage beds above it, and by a vast abundance of characteristic species in the top beds of the Hamilton Upper Shales below it, he could map the Genesee outcrop over the whole region; but he saw no trace of the Tully limestone or of its special New York fossils.

His generalized section† of the Hamilton upper shales shows at the top, just under the Genesee, 30′ of shales so extraordinarily fossiliferous that they yielded to his collec-

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* T3, p. 107, 184, 198.—At Mapleton, under 45′ of black Genesee shales (with thin sandy limestones holding large numbers of Goniatites and other shells) come 100′ of black fissile shales (without fossils), and then 5′ of grey impure limestone beds (with *Ambocœlia umbonata* and other shells badly preserved), and then Hamilton upper shales with *Homalonotus*, *Heliophyllum*, *Spirifera* and *Stictopora*.—In the Patterson section, under 120′ of blackish Genesee shale (holding large numbers of *Avicula speciosa* and *Goniatites complanatus* in the top layers) come 75′ of yellow shales, then 55′ of olive shales (with crinoids, etc.), then 5′ impure (Tully?) limestone (with *Atrypa reticularis* and crinoids), and then 175′ dark Hamilton upper shales, slightly fossiliferous.—At McConnellstown, under 250′ of Genesee black and olive shales 2′ of Tully? limestone is visible lying on 400′ of Hamilton shales and central (upper) sandstone. It is plain that there is no rule about the fossils, no strict agreement between the sections, no certainty of the identity of the 5′ limestone, but only a strong probability arising from the fact that it underlies the Genesee black shales.

† Report F2, 1885, Perry county, page 69.

tions more than a hundred described and undescribed species, most of them named in chapter LXXXIX page 1283 above. The upper 15′ he named the *Fenestella shale;* the lower 15′ the *Tropidoleptus shale;* no clear line of demarkation however between them, but the Fenestella generally in great profusion at the very top, under the Genesee, and therefore at the horizon of the Tully. To make the situation still more striking 200′ of almost non-fossiliferous shales come next below; so that this Fenestella-Tropidoleptus zone is locked in between the barren Genesee above and the barren Hamilton below. If then this zone does not represent the Tully, or *Cuboides zone* of Williams, what does it represent? I cannot see that the absence of *Atrypa cuboides* (*Rhynchonella venustula*) from this perfectly well marked horizon on the Delaware, Susquehanna and Juniata rivers in Pennsylvania is of the slightest value except to a Palæontologist who cares little or nothing for rock sections. In fact I cannot but regard this as a flagrant instance of the superiority of Stratigraphy over Palæontology in any broad study of our formations.

Chapter LXXXXI.

VIII e, Genesee black slate.

This formation was first studied in New York state by Vanuxem and Hall before 1840; and simultaneously in Pennsylvania and Virginia by the brothers H. D. and W. B. Rogers, who agreed to call it the *Cadent Upper Black Slate*, and it is described under that name in the Geology of Pennsylvania, Vol. 1, 1858.

In New York and in other states it is a black laminated mud formation, with wall-like outcrops; but where its surfaces are exposed it weathers into loose leaves; often iron-stained on account of the abundance of iron pyrites; but usually deep black.* It is a mere repetion of the *Marcellus formation*, or a return to the black mud deposits which had been partially interrupted by an invasion of sand.

The formation is remarkably uniform from top to bottom the whole length of its outcrop; the only interruption being two level stages or horizons of limeballs (*Septaria*), showing that twice during the long subsidence of black mud the sea had received a certain infusion of limewater, but not enough to make limestone beds, nor lasting long enough to encourage the growth of shells or corals. The particles of carbonate of lime had merely concreted into round balls of nearly pure limestone, of all sizes varying from a few inches to two or three feet in diameter; many of them cracked and recemented with crystalline lime (calcite); many quite whole, without flaw, entirely composed of calcite, of a deep rosin-color produced by bitumen which sometimes flows from them when they are broken. The

* *Coal beds* were supposed to exist in it by the early settlers of Cortland Co., N. Y., who accepted an Indian tradition to that effect at the foot of a steep hill near Preble Corners.

same kind of balls lie scattered singly throughout the whole formation.*

On Seneca lake and in Ontario county the *Genesee* is about 150′ thick, carefully measured in ravines and cliffs. After passing west of the Genesee river it is evidently thinner; and at its complete exposure on Lake Erie (eighteen mile creek cliff) only 23½ feet. †

From Cayuga lake eastward the outcrop can be traced fifty miles to Smyrna on the Shenango river (90 miles west of Albany) but no further. If the formation was deposited in eastern New York it was a sandstone.‡

VIII e. Genesee fossils in New York.

Fossils are rare, except in the upper 10′ or 15′ of the formation, where they are equally abundant all along the outcrop. The fullness of life in *Hamilton* times was extinguished by the invasion of black mud; as had happened once before when the *Marcellus* deposit was thrown down upon the *Corniferous.*

On Seneca lake, below Lodi falls, the Genesee abounds in its few peculiar species, Orbicula and Lingula the most abundant. In the gorge of the Genesee river its principal

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* Pyrites is found in the cavaties of these concretions. The carbonate of lime is in rhombic crystals; also in hexahedral crystals with trihedral summits. Sulphate of baryta, and quartz, more rarely galena, are also crystallized in them. Fluid bitumen is common; and a bright blue fluid; also a substance like but softer than spermaceti. The same occur in the *Marcellus* concretions.

† There is no sign of erosion. It is thinned by a lack of deposited matter, and the thinning goes on gradually for 150 miles (Hall, 1843, p. 221). Vanuxem gives it only about 100′ on Lake Cayuga; but his estimates are not so reliable (Van. 1842, p. 168).—Its best exhibition, where it got its name, is on the Genesee river, in the gorge at Mount Morris. Here it shows two distinct courses of balls, concretions or *Septaria*, besides others scattered about in it singly and without order of place.

‡ The change seems to be sudden; for west of Smyrna its black belt marks the country in Fabius, Truxton, Preble and Tully; at the head of Otisco lake; at the head of Lake Skeneateles; in Scipio; along Cayuga lake west of Venice, Genoa and Lansing; in the Ludlowville ravines 80′ to 100′ of it visible, at the high falls in the third ravine, made curious by the rock joints. Two of these joints are filled with veins of semi-crystalline serpentine and limestone looking like trap; two other similar veins traverse it at the foot of the second falls in the same ravine (Vanux. p. 169).

fossil is the little *Aviculopecten* (*Avicula*) *fragilis* which abounds in every exposure of the formation between the Genesee river and Lake Erie, as it does in Pennsylvania. This delicate little shell frequently quite covers the surface of the thin laminæ or plates into which the black shale splits; and that, through several inches of thickness of the rock. It is however sparingly scattered through the whole formation.* (See its figure, reduced, on Plate CLXVII, page 1296 above, near bottom of plate.)

Going east towards the little lakes of middle New York the *A. fragilis* becomes less numerous, and several other little shells are seen with it, but only in the top layers of the formation; viz: *Chonetes* (*Strophomena*) *setigerus* and *Tentaculites fissurella*, both species found in the Marcellus black slate; *Crania* (*Orbicula*) *lodensis*, a little round shell smoother than the Hamilton species; *Rhynchonella* (*Orthis*, *Atrypa*) *quadricostata*, quite abundant, in the lakes, but absent at Lake Erie; *Lingula spatulata* a narrow little form only about $\frac{1}{10}$ in. long; and *Lingula concentrica*, broader and only about $\frac{1}{5}$ in. long. Vanuxum mentions also a smooth seaweed like a blade of grass, only $\frac{1}{5}$ in long (1842, p. 168).

VIII e, Genessee in E. Pennsylvaina.

In Pike and Monroe counties north of the Delaware river the formation is never jet black, but bluish black, or when sandy merely a dark grey. It is well exposed two m. above Port Jervis, dipping 10°, N. 25° W.; quite fossiliferous with *S. mucronata. Athyris spiriferoides*, *Microdon bellistriatum*, *Trop. carinatus*, and many other shells. Two rows of clay ironstone balls are conspicuous along the bluffs near the bottom of the formation. Its line of outcrop through Pike county is indicated by a shallow narrow vale between the Hamilton sandstone outcrop on the south

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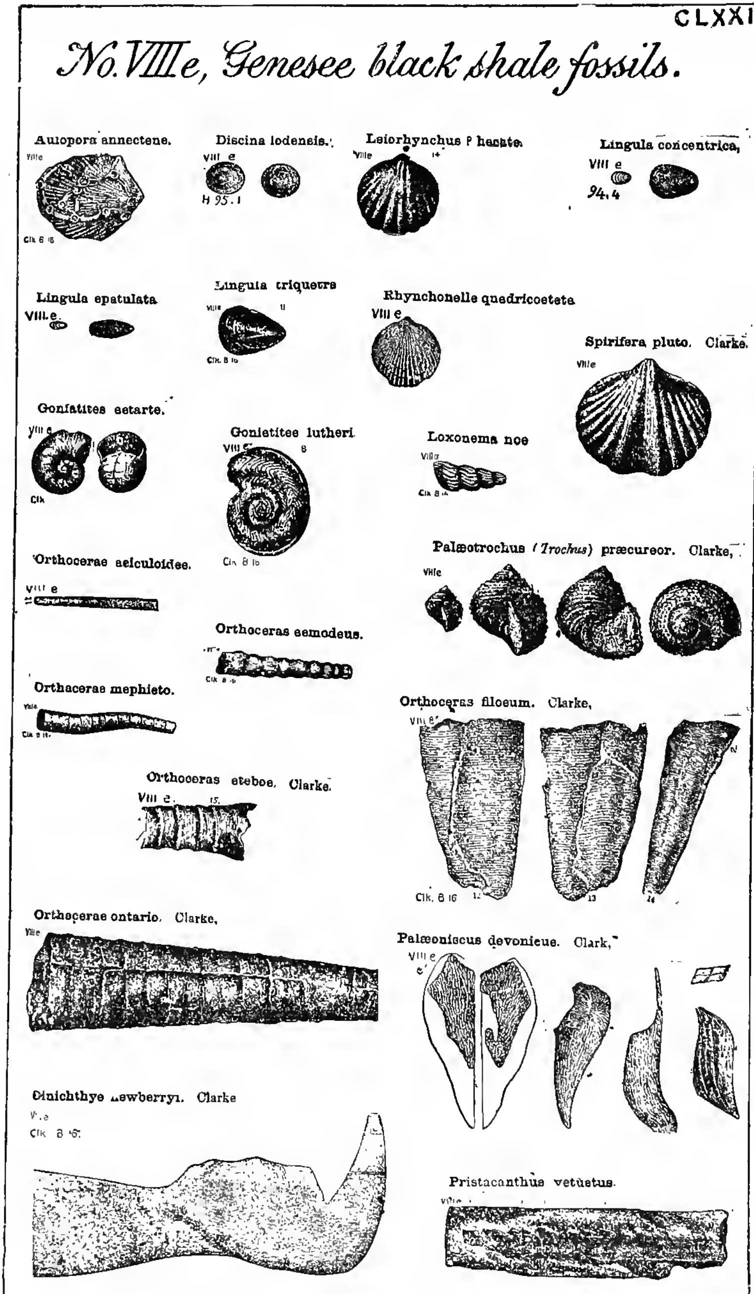
*In the coral bluff on Lake Erie (at Eighteen Mile creek) these little shells are so crowded together that for many feet in extent it is nearly impossible to distinguish their forms. This same shell lived in the *Marcellus* mud. It was an exceedingly thin shell, marked by concentric lines and a few faint radiating striæ, the hinge line shorter than the width of the shell, and usually concealed in the rock.


CLXXI
No. VIIIe, Genesee black shale fossils.
Aulopora annectens.
Discina lodensis.
Leiorhynchus ? hecate.
Lingula concentrica,
Lingula spatulata.
Lingula triquetra
Rhynchonella quadricostata
Spirifera pluto. Clarke.
Goniatites astarte.
Goniatites lutheri.
Loxonema noe
Orthoceras aciculoides.
Palæotrochus (Trochus) præcursor. Clarke,
Orthoceras aemodeus.
Orthoceras mephisto.
Orthoceras filosum. Clarke,
Orthoceras stebos. Clarke.
Orthoceras ontario. Clarke,
Palæoniscus devonicus. Clark,
Dinichthys newberryi. Clarke
Pristacanthus vetustus.

and the higher hard Chemung escarpment on the north. The beautiful cascades of Pike county usually begin at the base of the Genesee shale, the narrow cañons above the heads of the falls being cut through the soft dark Genesee shales, the waters then pitching over the sandstone strata of the Hamilton.

In Monroe county the Genesee outcrop runs from the Middle Bushkill falls to the Broadhead's creek bridge, 1¼ m. below Spragueville, and so on west to Pocono creek near Bartonsville, and then skirting the northern edge of Hamilton township, it bends through Jackson and continues west through the middle of Chestnut Hill and Polk into Carbon county, ½ m. N. of Kregesville, to cross the Lehigh river just above Lehighton RR. station.—Two other Genesee outcrops uniting round the east end of Wire ridge follow the opposite bases of the ridge to the Lehigh ; the one dipping S. reaching the river just below Lehighton; the other dipping N. about 30 rods above Bowman's.

Throughout these long lines from the Delaware to the Lehigh the Genesee seems to maintain a pretty constant thickness of 200′; a fact on which we base the logical inference that the formation underlies all our northeastern and northern counties and spreads beneath middle New York up to the northern outcrop already described.*

* For general description above see White's Report G6, p. 107 to 109. For details see G6, pp. 199, 213, 229, 255, 271, 288, 302, 305, 312.—*The Sawkill canon* above the falls is 110′ deep, 50′ wide at the top and 15′ at the head of the cascade. The uppermost fall is 20′ in two cascades over the *coral bed* at the base of the Genesee (Tully). The next is 60′ over Hamilton sandstone. The third (only 2½′ wide) is 15′ in a chasm walled in with precipices 75′ high.—The Middle Bushkill cañon is inaccessible ; a sloping cascade of 15′ is over sandy slates ; under which are 30′ of bluish rock, a complete mass of corals, honeycombed and pitted by weathering, the individuals countless, and the species numerous (Tully).—In Middle Smithfield the coral outcrop and the black slates are constantly concealed by piles of Chemung *débris* and Glacial drift.—At Marshall's Falls the Genesee is buried under Ruliff's run.—At Broadhead's creek it is concealed under Hoffman's run.—The formation makes a black belt on the road E. and W. ¼ m. N. of Custard's mills.—In Eldred township the dark sandy slates are exposed for a short distance along Prince's run.—In Polk, they are exposed with strong S. E. dip along the road S. of Big creek.—In Jackson they make a black band between Newhart's and Shook's.

The two Lehighton outcrops run on west and unite in a point before reaching the Little Schuylkill. The southern or Bowman's outcrop runs on into Schuylkill county, and unites near Pinegrove with a south dipping outcrop which returns east at the foot of Summer Hill and swings round southwards to Auburn on the Schuylkill, and then can be followed in a straight line S. 60° W. to the Swatara river dam and to the Susquehanna river above Marysville in Perry county.

VIII e, Genesee in Middle Pennsylvania.

The numerous zigzags which the outcrop makes in the region of the Lower Juniata, especially in Perry county, are indicated on the map plates CVIII, CIX (on pages 763, 765 above); and plates CXX, CXXI (on pages 966, 968 above); and in Union and Snyder on the map plate CXXVI (on page 984 above).*

In Perry county Prof. Claypole did not recognize the formation with certainty until he had studied for a long time the Portage shales over it and the Hamilton shales under it, because of its almost total barrenness of forms of organic life. Its bottom beds yield the N. Y. Genesee shell *Stytiola fissurella.* Its total thickness is not more than 200′.†

The difficulty of studying the formation may be guessed from the fact that in all Centre township, Perry county, there is but one exposure, namely, on the road from New Bloomfield on the south side of Mahanoy ridge (F2, 207). The barren shales whiten in the weather (F2, 280). In Wheatfield township the Portage shales with Portage fossils are well exposed at the mouth of Losh's run, but the

* Consult also the small local fault map of Spring township Perry Co., on plate XCII, p. 662 in Vol. 1.

† A remarkable case of bad geological observation was displayed by the assignment of First Survey thickness of 1200′ to the outcrop near Newport on the Juniata. The error was made by overlooking the eastward extension of the fold at Inoculate Run. A set of small anticlinals come in from the west crimpling and overturning the dips. Prof. Claypole gives warning that "extreme caution is required in obtaining dimensions in Perry county; concealed folds, extention of anticlines, and the presence of faults destroy the value of many exposures for this purpose" (F2, pp. 69, 71).

Genesee is as usual obscure (F2, 391). It is noteworthy that this black mud deposit in New York should have so changed its character in Perry Co. Pa.

At Selinsgrove in Snyder and Northumberland counties Prof. White describes the Genesee as dark bluish slaty beds, 264′ thick (visible), with only one 4′ bed of *real black slate* noticeable, lying 30′ above the bottom; and so barren of animal life-forms that he only found one shell (*Discina lodensis ?*) 120′ above the black bed. (G7, p. 78).*

On the North Branch Susquehanna the formation is at least 275′ thick, as seen in Prof. White's fine section in Columbia county on Fishing creek.† Its dark blue and blackish sandy shales and slates, weathering gray, are finely exposed and accurately measured, and seem to be entirely destitute of fossils. Over them lie 45′ of grey shaly beds, so much less sandy than the still higher Portage strata that they might perhaps be called Genesee, making this 320′ thick.‡ A fine cliff of Genesee shale, 150′ high, rises from the east bank of Fishing creek opposite the road forks near D. McHenry's, the strata dipping southward only 5° or 6°.

In Snyder county the dark blue, brown and black shales, weathering yellow, make continuous outcrop valleys at the

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* He says that the formation may be somewhat thicker than 264′, since there is beneath it an interval of 400′ of concealed rocks before the first Hamilton exposures appear (G7, 361).

†G7, p. 225, 228; and page plate p. 222, for a copy of which *half-size* see low figure on Plate CLXXV in a future chapter in this volume on the Chemung formation.

‡ G7, 286, 228. At Catawissa it is about 300; at S. Danville 300′ perfectly exposed and no fossils seen; at Bloomsburg 270′; on the river between Cat. and Bloom. ferry 275′, where close search yielded no fossils, the shales when long weathered being bleached nearly white. No fossils also on Ten Mile run (G7, 243, 277, 281, 287, 290, 351). In the Wapwallopen section only 30′ of dark blue slates emerge from the valley. They appear also on Nescopec creek at Evans' grist mill in Luzerne county. In Columbia county black shale adjoins the Tully limestone. An arch of these shales is made by the Milton anticlinal just below Ayers' Grove, at the S. W. corner of Greenwood township.

foot of the Chemung-Portage hill-ranges; the formation being about 300′ thick, and seldom exposed for study.*

Mifflin county has preserved in none of its synclinal troughs any formation higher than the Marcellus. All above, including the coal measures, have been swept away.

Huntingdon county on the contrary has two long outcrops of Genesee in the Aughwick valley; and a third along Hare's valley between Jack's mountain and Sideling hill, which passes Mapleton; runs up Mill creek; sweeps round north to Standing Stone creek; returns S. W. to the Juniata at Huntingdon; and continues on to and through Bedford county into Maryland. Two more traverse the Tuscarora valley from Juniata county to and through Fulton county into Maryland.§

Ashburner's description of the Genesee in Aughwick and Hare valleys shows how uncertain are its limits and how little it differs from the Portage shales above it and the Hamilton shales beneath it. He makes four divisions measuring (from top down) 100′+75′+100′+50′=325′ of olive shaly and slaty sandstone beds, alternating with brownish grey flags and dark olive shales; towards the bottom the sandstone layers disappear, the shales become clay shales, and at the bottom are dark olive fissile slate, with an occasional bright olive sandstone layer only 2 to 4 inches thick. He adds, *the shale and slate are slightly bituminous*, and are also iron stained (F, p. 223, 227).

At Mapleton on the Juniata river the bluish black nearly

* In Perry township near Reichenbach's they appear on steep dips (30° to 60°).—In Juniata county they may be examined for a mile along Turkey valley at the Seven Stars hotel, dipping 15°, N. W. Also on Dutchman's run and at Dimmsville in Greenwood township. But in Tuscarora township on the road over the hill to Waterford is a very fine exposure, 25′ thick, dips 35°, S. E (F3, pp. 46, 214, 318, 380).

§ The Genesee slate range crosses Ashburner's E. Broad Top section line at the W. end of Sypestown gap, in Jack's mountain; descending the ravine between Hooper's and Nelson's houses; the slates dipping 29°, (S. E.) increasing to 50° at the Marcellus ore bed (F, p. 167, 168). On his Sideling hill section the top of the Genesee, E. of Wollard's house, dip 68° N. W. It recrosses Sideling Hill creek 4000′ further south (F, 174, 175).

vertical outcrop of the Genesee, holding thin sandy limestone layers and great numbers of fossil shells, 45′, with underlying *black* fissile shales, 100′, and a bottom (Tully) impure gray limestone, make a bold line of separation between the Hamilton shales beneath and the Portage flags above, at the railroad bridge a mile above the town. Here, only 10′ to 30′ beneath the lowest Portage flags, were collected the fossil shells: *Lunulicardium fragile*, *Cardiola doris*, *Goniatites patersoni*, and *Orthoceras aciculum.* From the same top beds of Genesee on the road from McConnellstown up Piney ridge Prof. White collected *L. fragile*, *C. doris*, *Cardiola speciosa*, *Goniatites complanatus*, *Orthoceras subulatum* and *Styliola fissurella.* In fact, at all exposures of these top beds Prof. White collected this group of shells: *Lunulicaridum*, *Cardiola* and *Goniatites.* But the *C. speciosa* was collected also from Portage beds 100′ or 200′ higher.

The Genesee shales are not always *black from top to bottom*, as they are at Mapleton. Some are dark grey; but in every section in Huntingdon county at least 20′ or 30′ are black. (T3, p. 107, 108).

In Fulton county the Genesee is generally concealed, but Prof. Stevenson saw it exposed on Tonolaway creek near the north edge of Thompson township; and on the west side of Tonolaway ridge in Bethel township (T2, 82).

In Bedford county it is well seen on the Pittsburgh pike at Colvin's in Napier; and fairly at Westone's; elsewhere very indefinite. On the pike it measures 420′. In the section N. E. of Saxton it is much less, for a concealed interval of 237 carries from the last seen Hamilton to the first seen Chemung (Portage?) bed. On the Pigeon Cove axis in Fulton it is certainly little more than 150′. The beds are mostly of dark shale; but there is not a little brown shale; and some olive flags. (T2, 82, 117).*

*Rogers quotes remarkable Genesee exposures on the Potomac:—415′ at Sidling Hill gap; and 700′ near Cumberland; increasing southward through Virginia; then decreasing and vanishing in eastern and middle Tennessee. The New York outcrop through Ohio and Indiana feathers out in northern Illinois (Geol. Pa. 1858, p. 140).

In Blair county, the valley of the Little Juniata (Tuckahoe valley) is excavated along the upturned outcrop of an indistinguishable pile of dark shales estimated by F. Platt on the basis of Sanders' measurement to be 1365′; the upper grey and brown *Genesee* being partly flaggy at the top and olive and sometimes bright brown, slightly bituminous and iron stained; the lower black part *Marcellus*; the middle (*Hamilton*) olive shales being as soft as the others. Of course the Genesee cannot be exposed to view (T, 15, 31). Rogers' estimate of its thickness at Frankstown was 300′ or 350′.

Across Centre county the same conditions prevail, the Genesee very dark shales lying on the N. W. back of low shaly decomposable Hamilton hills. D'Invilliers calls the Genesee in Boggs township 200′. (T4, 276, 287).

In Clinton the *Genesee* outcrop crosses the river above Lock Haven, and according to Dr. Chance's section is a mass of soft dark grey and olive shales, with some bands of slate, in all 560′ thick (1131′ above the top of the *Marcellus* formation; this interval being entirely soft *Hamilton* shales with a few flags). The top of the Genesee has evidently been taken at the base of 189′ of hard *Portage* sandstones. (G4, p. 128).

In Lycoming county the Genesee outcrop is covered with river mud, until it emerges and makes its bend round Muncy and back into Union county. In the Muncy hills Rogers gives it a thickness of 250′ or 300′; and in White Deer Hole valley of 200′ to 300′.

In the northern counties the Genesee lies buried deep. It was struck in the Ithaca well at 440′ beneath the surface, and is called by Prof. Prosser 100′ thick.

VIIIe, Genesee fossils.

The only specimens in the collections of the Survey from any district in the state are those mentioned on page above as obtained by White from Mapleton and McConnellsburg, viz: *Styliola fissurella; Cardiola doris* and *speciosa; Lunulicardium fragile; Orthoceras aciculum* and *subulatum; Goniatites complanatus* and *patersoni*. (Report Cat. O3, pp. 167, 170).*—In Western New York several of these shells are confined to the local formation called by Hall the *Cashaqua shale*, which he made the bottom of his *Portage group*; as will be seen in the next chapter.—In Ohio the Genesee (if it be the Ohio "Black shale") contains few fossil species notably *Lingula subspatulata* M. & W., a *Discina*, a *Chonetes*, and many remains of *Crustaceans* and *Fishes*, described and figured by Dr. Newberry in the State Reports. The *Dinychthys* terrible fish) *herzeri*, covered with an armor of bony plates, its head 3′ feet long by 2′ broad, and under jaws 3′ long, brought to a knife edge set with saw teeth above, and ending in upturned fang of bone, must have been 20′ long.† The remains of these monsters are so numerous that the sea must have swarmed with them. Great sharks also existed, one spine (*Ctenacanthus vetustus*) a foot long having been found. *Dinichthys newberryi* had a sharp knife edge jaw without sawteeth. Another species has been found in the Portage in western New York.‡—Large winged insects existed, as shown by the fragment of a neuropterous wing *Platephema antiqua* found at St. John, N. Brunswick, and described by Scudder. It was a may-fly, with a spread of wings 5″ across, living its larval life in the water, and humming in its maturity over black muddy

* In Claypole's collections *Tropidoleptus carinatus* is mentioned as collected by White from Genesee at Huntingdon; from Hamilton at Paxinos quarry, North. Co., Cat. O3, p. 147, 168).—Also *Strophodonta perplana* is reported from Portage (Cardiola shale; the same as New York Cashauqua or Genesee shale p. 147).

† See a very reduced drawing, from Newberry's large plates, in Report P4, Dict. Foss. Pa., etc., Vol. 1, 1889, p. 202.

‡ Ringueberg in A. J. Science, June, 1884. The formidable jaws were required to break through the shagreen hide of the sharks as well as to crack and crush the armor of other placoderm fishes then living; and no doubt the big Ds fed also on the little ones. That none of these fishes have been found in Pennsylvania agrees very well with the altered color and character of the formation coming east; for the grey sandy beds in our state have no resemblance to the black mud strata of Ohio, although of the same age. The depth of the sea, the influx of material into it, and the species of animals inhabiting it, must have been very different.

shallows in a wilderness of reeds and cane brakes, for Calamites and Asterophyllites are not uncommon in the Hamilton rocks, and Scudder detects a stridulating organ in one of his insect wing specimens. (See Dana's Man. Geol. 1880, p. 273, Fig. 550 A.)

VIII e. Genesee petroleum.

The "Black shale" formation of Ohio and the states west and south of it, the "Huron formation" of Michigan, is identified by Dana and others with the *Genesee*, but by S. A. Miller and others with the *Portage*. In Ohio it is charged with 10, in Tennessee with 15 or 20 per cent of absorbed non-soluble petroleum, studied chemically by Sterry Hunt, where further west the tarry element fries out of its outcrops under the summer sunshine. Newberry calculated that the 350′ of Ohio black shale were equivalent to 40′ of coal. No oil wells produce petroleum from it, nor will any chemical solvent separate it; but the lighter hydrocarbons are set free naturally, making permanent *gas springs*, as at Fredonia, N. Y., and elsewhere; and in future times when the petroleum production has been exhausted and our cities must again be lighted by artificial coal shale gas by Young's process this "black shale" formation will yield an infinite supply.

The origin of its petroleum is unknown. It is perhaps possible that the fine clay of this formation has absorbed it from the decomposing soft substance of the world of fossil life in underlying formations, notably the Corniferous and Lower Helderberg.* It is a well known property of

* In opposition to this theory is the fact that the Helderberg beds lie beneath the Hamilton which ought to have been charged with ascending oil first, and still higher rocks afterwards. But the Hamilton is almost entirely destitute of such black slates, and none of its sandrocks contain petroleum. This shows how impossible it is that the very much higher Venango and other oil sand rocks of Pennsylvania could have received their petroleum *from below*. In my future summary chapter on the oil measures of Pennsylvania, I will give the evidence for the native origin of petroleum in the oil-bearing formations themselves. If this evidence be accepted it ought to establish the principle that the older oil formations and petroleum gas shales were charged *by their own fossils* and not from lower fossiliferous formations. It must be remembered that seaweeds are the chief producers of petroleum in all ages up to the present day, and the oil

all fine clays to take up oil of any kind and hold it for an indefinite time, during which its chemical decomposition goes on, more or less slowly in proportion to the access of underground water, or to the access of air allowed by the erosive lowering of the surface outcrops. Part of the petroleum in these shales may be of vegetable origin, for they have a considerable percentage of sulphur now chiefly in combination with the iron of the original clay sediments, as pyrites ; hence abundant efflorescence of copperas and alum in sheltered places, and numerous sulphur springs along all the outcrops. In the next chapter will be found a summary of Prof. J. C. White's Report Q4 on these phenomena in Erie county, Pa.

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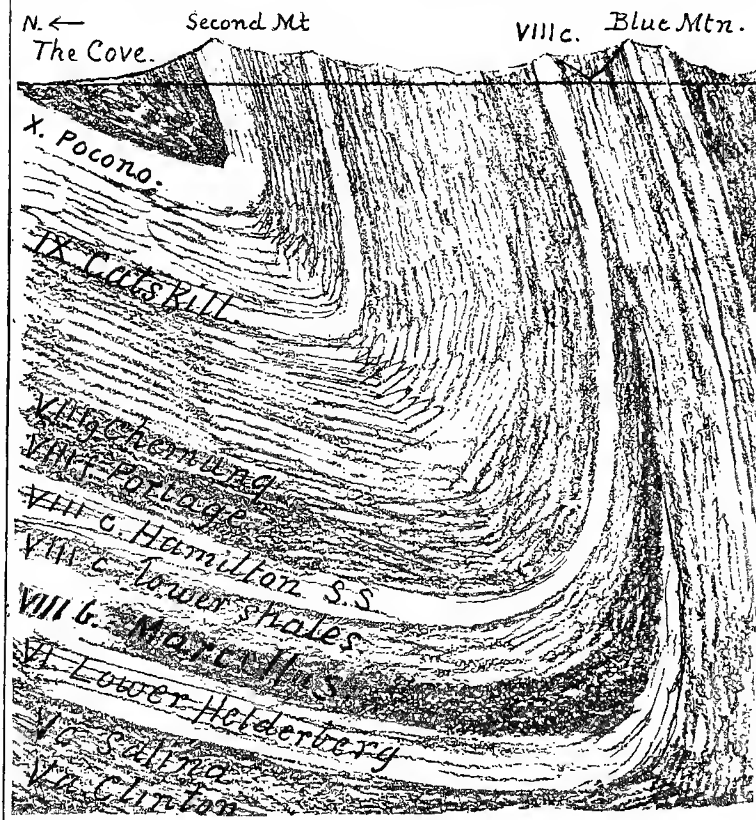
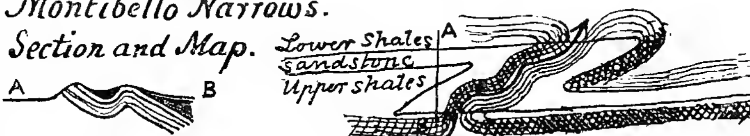
producing quality of an ancient sediment must not be gauged by the abundance of shell beds in it. Moreover, we know almost nothing of the infusorial life of palæozoic formations, and nothing at all about the oil producing power of infusoria.

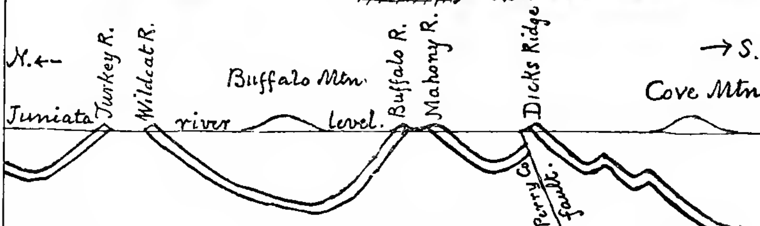
Chap. 88. CLXXXXIX

VIII c, Hamilton terrace in the gap above Harrisburg.



Montibello Narrows.
Section and Map.





CHAPTER LXXXXII.

VIII f. The Portage formation.

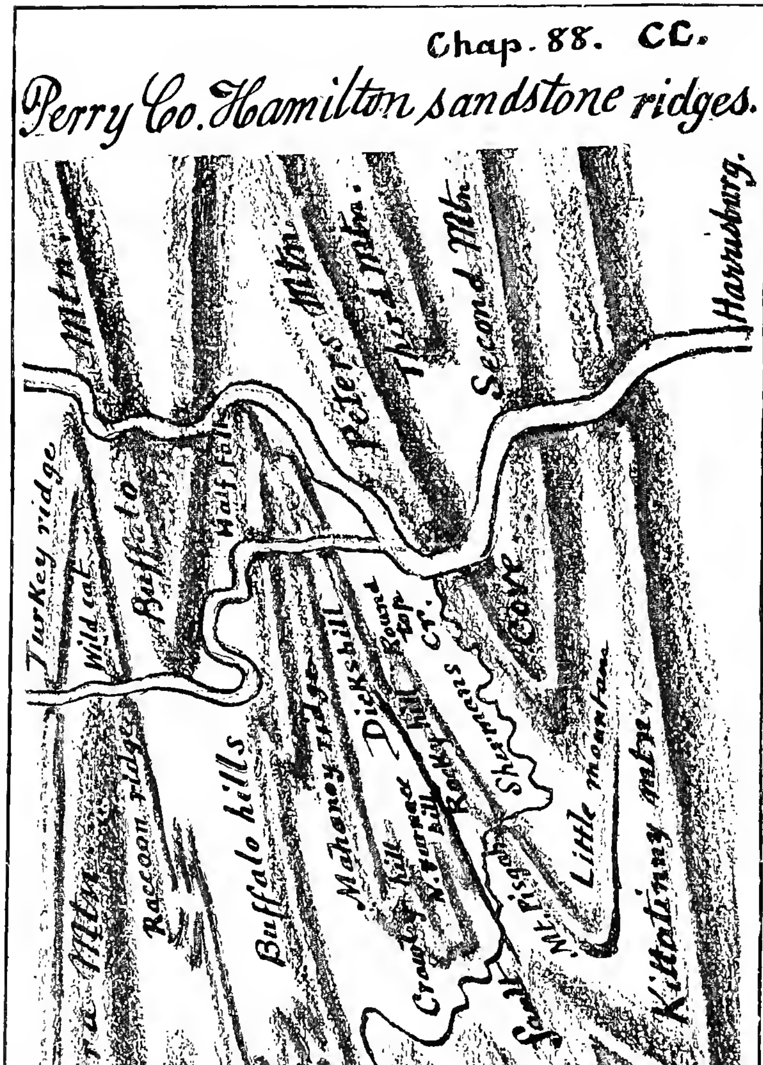
The Portage formation was named in western New York from the three high falls of the Genesee river, which impeded its navigation, compelling the Indians to carry their canoes from the higher to the lower level, or *vice versa*, and the engineers of the Erie canal to construct a staircase of locks.* The river flows north,† descending a narrow gorge, between steep cliffs of flagstone strata, rising at the rate of only 40 or 50 feet per mile towards Lake Ontario. The river drops from stratum to stratum through the *Portage flags* into the *Gardeau shales;* cuts through these to the *Cashaqua shales;* and then through these to the *Genesee black slate.*

Thus the whole formation can be examined and measured. It is scarcely less than 1000 feet thick.‡ No *Chemung* fossils are found in it; for which reason it was made a separate formation in western and middle New York. Farther east it turns into the *Oneonta sandstone* formation, forerunner of the Catskill, IX. Nor can it be distinguished from the *Chemung* in many parts of middle Pennsylvania, where both formations have a much greater thickness, and a closer resemblance.

*The upper fall is 66′, the middle 110′, the lower 95′. See Prof. Hall's long section No. 1, Report of 1843, Plate XIII; and Mrs. Hall's picture of the upper and middle falls on page 244.

†The Genesee is the only river of northern Pennsylvania which continued to flow north after the ice age. All the others to the east and west of it were dammed by moraine matter and compelled to cut new channels southward (see Reports I3 and Q4).

‡The thickness of 1000′ on the Genesee river is got by adding to 600′ of river fall, 300′ for dip in ten miles, and 200′ of top most strata. On Lake Erie the thickness must be 1400′, since it extends between thirty and forty miles to the mouth of Chautauqua creek, in which 300′ or 400′ more are exposed. Were we to judge of the thickness of the formation by the great breadth of its outcrop belt east and west through New York we should be obliged to make it much greater than these figures; were it not for some gentle undulations which broaden the belt without increasing the above estimate, based on an average dip of 25′ to the mile, and that in spite of the fact that in many localities the dip is twice as great.


Chap. 88. CC.
Perry Co. Hamilton sandstone ridges.
Harrisburg.
Second Mtn.
Third Mtn.
Peters Mtn.
Half Falls
Buffalo
Turkey ridge
Wild cat
Cove
Dicks hill
Round top
Sherman's Cr.
Mahoney ridge
Raccoon ridge
Buffalo hills
Little mountain
Kittatinny mtn.
Mt. Pisgah
Crow's hill
N. Furnace hill
Buffalo
Tuscarora Mtn.
Sandy hill
Sand hill
North mtn.

The same is true of its sub-divisions, which are so distinct on the Genesee river. Going east, the deep green *Cashaqua shales* gets darker and more sandy, even largely interstratified with flagstone beds, quite like the *Portage flags* (except in the absence of a peculiar seaweed); and what is more important gets to be as full of little *Aviculopecten* as the *Genesee black shales* beneath it themselves are.

Going westward from the Genesee river to Lake Erie—instead of *Portage* flags lying immediately upon light green *Gardeau*, and deep green *Cashaqua* shales, we find the flagstones supported by many hundred feet of *alternate green and black shales*, the lowest black resting on green *Cashaqua*, and that upon black *Genesee** (Hall, p. 218).

The topography produced by the *Portage formation* along its New York outcrop is worth studying, and helps to explain the appearance of the shapes of the hill ranges which its outcrops make in Pennsylvania. Between each pair of north and south valleys a tongue or tooth of *Portage strata* projects northward, gradually rising and ending in a commanding pointed spur. At the same time each valley sinks lower and lower, between hill slopes which are at first gentle and low, then gradually steeper and higher, with many lateral ravines; until at length the valley escapes upon the *Hamilton* low grounds from between hills the tops of which are four, five and even eight hundred feet

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* In Pennsylvania nothing like this is seen ; and it may be a question if the whole mass of alternations be not the *Genesee black formation* with intrusions of green slate from another source. The *Cashaqua* shale on the Genesee river has a black shale bed, exactly like the *Genesee*, eight feet above its base. Its identification with Winchell's *Huron Group* in southern Michigan is confusing. The New York belt extends west through Lake Erie diagonally, and across central Ohio to the Ohio river below the mouth of the Sciota, and across Kentucky. The Michigan outcrop belt underlies the head of Lake Erie and sweeps S. W. across Indiana to the Ohio river at New Albany, and across western Kentucky. In the Ohio and Indiana Reports of 1838 and 1839, and in the later Reports of Indiana, Kentucky and Tennessee it is simply called the "black shales", a name more properly belonging to the Genesee. Its thickness westward runs down from 200′ to 100′ in Ohio and Indiana, and to 10′ in Tennessee (see S. A. Miller's N. A. G. & P. 1891, p. 63). The common identification of the "black shale" with the *Genesee* (not Portage) is expressed in Dana's Manual of Geology, 1880, p. 268. See what is said of its *petroleum* at the close of the last chapter on the Genesee.

in the air. All this is owing to the fact that the lower parts of the formation are much softer than the upper; that the amount of interstratified flagstone increases upward; and that the uppermost strata of all are of massive although fine-grained sandstone. Over the edges of these upper strata and also over the edges of the interstratified flagstones, in the ravines and in the main valleys, the streams of the region make some of the most beautiful cascades in the state.*

VIII f′. Cashaqua shale.

The *Cashaqua dark green shale*, on Cashaqua creek, is a soft crumbling mud rock, weathering down into a tenaceous clay. Fossils are not numerous, and are hard to find; some of them being peculiar to the formation along 150 miles of outcrop. Flattened lime-balls and sand-balls are scattered through it. Streams cut steep-sided serpentine ravines, partly bare of vegetation. It is 33′ thick on Lake Erie (mouth of Eighteen Mile creek) increasing to 110′ on the Genesee river, without changing its character; but occasionally dark colored; and separated from the *Genesee formation*, on which it rests, by a calcareous stratum. Between the river and Seneca lake (at Penn-Yan) it gets some interstratified thin flagstone beds and sandy shales which are concretionary and irregular in thickness and continuance. From Penn-Yan eastward it becomes more and more sandy; and at last the whole of it becomes merely thin bedded shaly sandstone, the lowest portion of the *Portage formation.*

In west New York it may be identified by its peculiar little lamellibranch shell *Avicula speciosa* with ten ribs crossed by concentric lines, the two valves often found attached to each other showing the quietness of the water in which it lived.† *Lunulicardium* (*Pinnopsis*) *acutirostrum* is another lamellibranch quite confined to the *Casha-*

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* Too numerous to catalogue. For example, the three Portage, the Taghannock, Hector, Lodi and other falls. Vertical cliffs 350′ high enclose the lower Portage fall.

† In Perry county, Pa. Prof. Claypole calls it *Cardiola speciosa*, and gives its name to his *Cardiola shales* (see F2, 69).

qua shale; with about 26 diverging ribs, crossed by faint undulating lines, and a few stronger wrinkles of growth; the beak extended, sharp and slightly incurved.—The very similar *Lunulicardium* (*Pinnopsis*) *ornatum* has 40 ribs. —*Cardiomorpha* (*Ungulina*) *suborbicularis*, nearly round, without ribs, and as large as a quarter of a dollar, is not uncommon but seldom found unbroken.—*Bucania* (*Bellerophon*) *expansa* is a small gasteropod.—The beautiful little needle-like *Orthoceras aciculum*, $1\frac{1}{2}''$ long, is always found changed into iron pyrites and its markings destroyed.—The flattened close-coiled cephalopod *Goniatites* (*Clymenia*) *complanatus* is also changed to iron pyrites.*—Besides which a large whorled shell (4″ maximum) *Goniatites sinuatus*, with wavy internal partitions, lived on into the next higher set of Portage shales, the Gardeau, now to be described.

VIII f″. The Gardeau shale.†

Over the Cashaqua deep green shales, along the Genesee river, lie green and black, slaty and sandy shales, with thin layers of beautiful durable flagstone, quarried at many places. The *upper* portion is an alternation of sandstone beds, too massive for flagstone, with shale beds also thicker than those below. The *middle* portion has distinct and frequent alternations of black and green shale with flagstones. The *lower* portion is of alternate green slaty sandy shale with black slaty shale and one or two courses of sandstone in a space of four or five feet. Towards the west the sand diminishes and the mud increases; at lake Erie the flags are almost all gone; and several hundred feet of green and black alternations overlie a thick mass of black shale resting on the Cashaqua green shale. Towards the east the shales disappear and the Gardeau becomes merely the middle portion of the Portage flagstone formation. In

* All the above mentioned shells are found in western New York *only in the Cashaqua shales.* In Pennsylvania they have been found by White in Huntingdon county, only at the top of his *Genesee*, as narrated at the end of the last chapter; and therefore the horizon is perfectly fixed, although the local New York name for it is unnecessarily confusing.

† So called from the fine exhibitions in the Gardeau reservation.

these soft green Gardeau shales (but not in the underlying Cashaqua) occurs the small triangular *Cardiola* (*Cardium*) *vetusta*, on Cashaqua creek, the Genesee river, and Lake Erie shore.

VIII f'''. The Portage proper.

The *Portage sandstones*, exposed for 350′ in the vertical cliffs of the Genesee river below the falls, are thick bedded with very small shale partings in the upper portion, and thin bedded with many shale partings in the lower. The upper thick beds are penetrated by *seaweeds standing upright;* the lower thin beds have their own special *seaweeds lying flat.** The vertical seaweeds are a good indication of the formation along stretches of the outcrop.

Westward, the thick bedded sandstones appear occasionally at Leona; at Shumla, on the railroad west of Fredonia, at several places on the shore of lake Erie; but the formation grows less massive, so that it crosses the state line into Erie county, Pennsylvania, 475′ of alternate layers of grey shale and hard sandstone (seldom a foot thick but now and then two feet) show above lake level, and gradually sink south westward, until the topmost disappears beneath the water within two miles of the Ohio state line (O4, 119).

Eastward, toward Cayuga lake (as said above) the *Portage sandstones* pass down without distinction into Gardeau and Cashaqua shaly sandstones, and the whole becomes one shaly sandstone formation.†. Not only so,

*Along Crooked lake, the middle and upper Portage strata are everywhere known by thin flagstones with under surfaces covered by the short, stiff stems of *Fucoides graphica* (see Fig. 104, Hall, page 241). At the south end of Canandaigua lake, the whole Portage is fully exposed; and it can be studied also in the ravines of Honeoye, Hemlock, and Canadice lakes; on Caneseraga creek; on the Genesee between Dansville and Mount Morris, especially on Cashaqua creek; very perfectly on Allen's branch of Tonawanda creek; the whole formation on the branches of Cayuga and Seneca creeks in Erie county; and on the shore of Lake Erie in cliffs from twenty to one hundred feet high all the way from Eighteen Mile creek, past the state line, to within two miles of the Ohio state line. The superposition of the Chemung formation upon the Portage can be studied in the top gorge of Chautauqua creek; but this superposition will be described in connection with the exposures of Portage and overlying *Girard shales* in Erie county, Pa.

†On Cayuga Lake, the lowest *Portage* (*Cashaqua*) layer is a sandstone,

but upward also, the distinction between Portage and Chemung becomes dim; is in fact merely a difference of general fineness and coarseness; the whole column of deposits from the Tully up to the Catskill being a confused alternation of sandy shaly strata; finer and more muddy in the Genesee; fine and sandy in the Portage; more coarsly sandy in the Chemung. The Portage sandstones are rather fine grained muddy flagstones; the Chemung beds are truer sandstones.

VIII f, Portage fossils.

Fossils strongly distinguish the Portage formation from the Hamilton beneath and the Chemung above it.* In both the *Hamilton* and *Chemung* brachiopod shells are ten times more numerous than shells of any other family; but in the whole 1000′ of *Portage* strata only two brachiopods (*Spirifera lævis* and *Orthis tenuistriatus*, both peculiar species) were recorded by Hall in his final report of 1843.

The principle *Portage* shells are cephalopods (*Goniatites* of several species), a gasteropod (Bellerophon), and lamelli-

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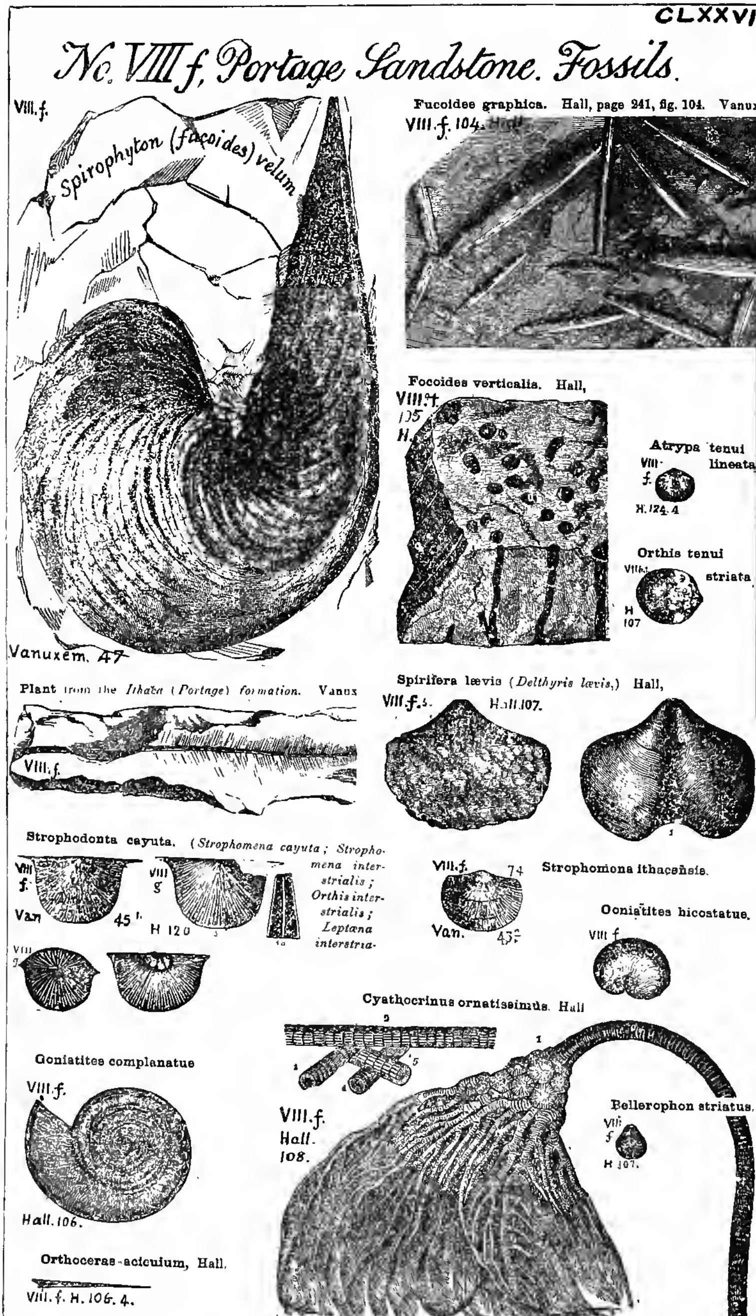
which the eye can readily follow southward as it dips towards the water, resting immediately upon the *Genesee* black slate. This layer, varying in thickness, but never exceeding three feet, very compact and solid, has an under-surface covered with multitudes of the *Fucoides graphica*, so commonly visible in relief upon the flagstones of the pavements of Ithaca, Homer, etc., with depressed ends, from one to two or more inches in length, somewhat quadrangular, the surface curved, and either separate or grouped in various ways and penetrating each other. Besides this bottom layer, others higher up in the series, up to the top of the inclined plane, contain the same fossil, but much more sparingly. Another kind of marking resembling fragments of narrow leaf grasses, invariably brownish-black, is seen upon the surfaces of strata from top to bottom of the formation, which presents a continuous picturesque cliff along the lake shore from near South Point northward for about two miles (Vanuxem, 1852, page 173).

*Fossil shells are confined to a few of the Portage beds; which fact being usually overlooked the formation has been often called non-fossiliferous. In Erie county, Penn., Prof. White found no fossils in it except the sea-weed *Fucoides graphica* (not the *verticalis*). The paucity of fossils in the Portage, compared to the formations above and below it is one of its most striking characters, "whole days may be spent in searching, in some parts of it without finding more than a few and perhaps even no shells." In a few favored localities some forms may be found not known elsewhere or in any other formation; unlike all other shells not only specifically but generically.


CLXXVI
No. VIII f, Portage Sandstone. Fossils.
VIII. f.
Spirophyton (fucoides) velum
Vanuxem. 47
Fucoides graphica. Hall, page 241, fig. 104. Vanux
VIII. f. 104.
Focoides verticalis. Hall,
VIII. f.
105
H.
Atrypa tenui lineata
VIII. f.
H. 124. 4
Orthis tenui striata
H
107
Plant from the Ithaca (Portage) formation. Vanux
VIII. f.
Spirifera lævis (Delthyris lævis,) Hall,
VIII. f.
Hall 107.
Strophodonta cayuta. (Strophomena cayuta; Strophomena interstrialis; Orthis interstrialis; Leptæna interstria-
VIII f.
Van
45
VIII g
H 120
VIII. f.
74
Van.
43
Strophomena ithacensis.
Goniatites bicostatus.
VIII f.
Cyathocrinus ornatissimus. Hall
Goniatites complanatus
VIII. f.
Hall. 106.
VIII. f.
Hall.
108.
Bellerophon striatus.
VIII f.
H 107.
Orthoceras aciculum, Hall.
VIII. f. H. 106. 4.

branchs (*Pterinea?* and the small beautiful and peculiar *Avicula speciosa*). There must be good reason then for separating the Portage from the Chemung, in spite of the general resemblance of their rock strata ; and it will seem that in some districts of Pennsylvania (Fulton county for instance) the resemblance ceases, although the distinctive aspects of the two are just reversed, the Portage having the coarse sandstones, and the Chemung the shales.

Fucoids are in great abundance. The one most abundant, which everywhere marks the *central portion* of the whole formation, is the *Fucoides graphica*, the short stiff fragments of which are spread in great confusion over the surfaces of the thin flagstone beds everywhere. Some of the finest specimens lie in the streets of Geneva. The beds of ravines are full of them. The *upper thicker sandstone beds* of the formation do not have them. But instead of that the small round stems of another sea plant, the *Fucoides verticalis*, standing upright as they grew in the sand, are most abundant; and the extreme *top beds* may be known by them. They appear in the rocks above and at the Lower falls of Portage. It is now well recognized that such *vertical* stems are not sea plants (fucoids) at all but but the burrows of worms coming under the vague general name of *Scolithus*, as described in Chapter XVIII of Vol. I, above. They appear in the upper Portage beds in Bradford and Tioga counties, Pa., if these be not in reality Chemung beds (See Rogers' Geol. Pa. 1858, 296.) *

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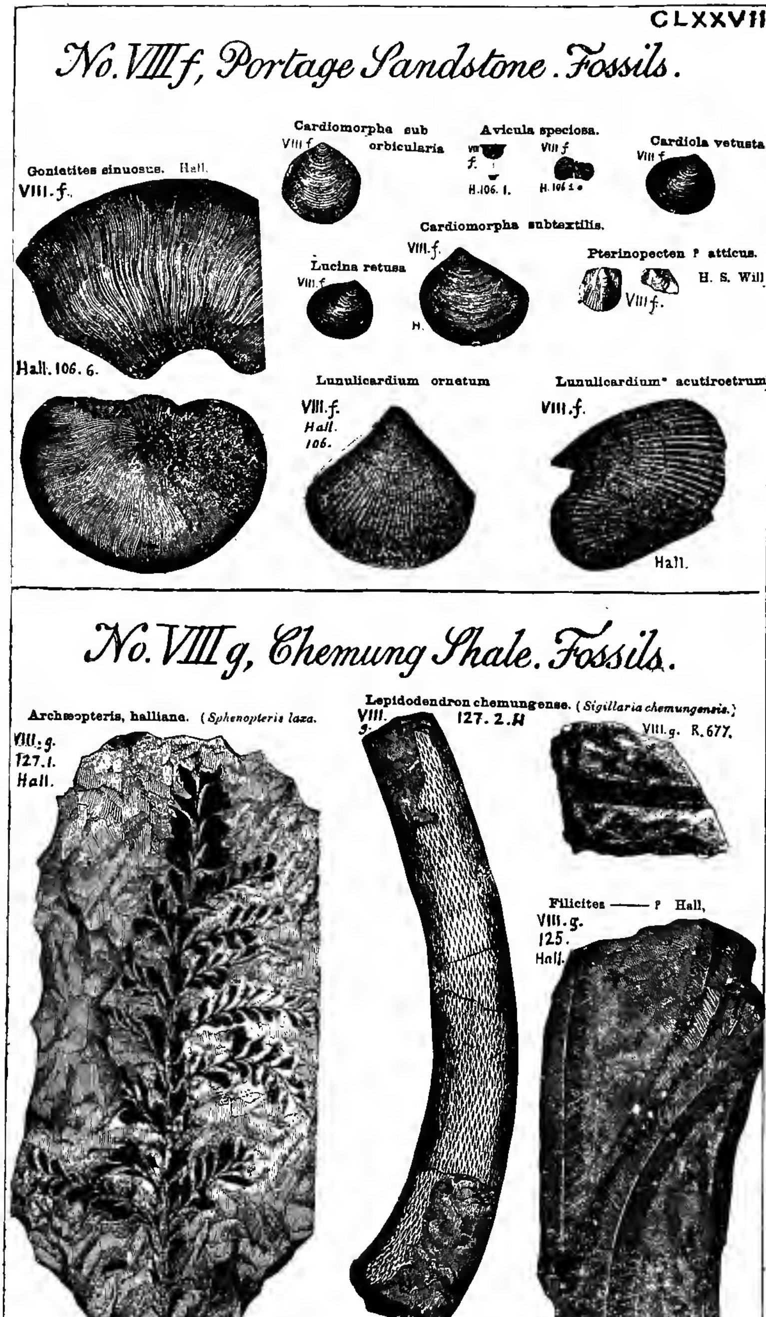
*The Genus Scolithus is treated by J. F. James, U. S. G. Survey, in a paper read before the Geol. Soc. at Washington, 1891, as "Problematical Organisms." He says that *S. shephardi* of the Trias does not differ in any essential respect from the *linearis* of the Cambrian; nor *S. verticalis* of the Portage from the *clintonensis* of the Medina and Clinton ; nor either of these last from the *linearis;* which is Billings' *canadensis* of the Potsdam. *S. minutus* of the Calciferous cannot be separated from the upper Cambrian *woodii* in the Mississippi valley, nor from the Cincinnati *delicatulus* except that the cavities of the tubes of the last are filled and not hollow. The St. Peter's *minnesotensis* has the character of *linearis.* The worms making all these burrows could not have been of the same species considering the immense lapse of time between Lower Cambrian and Trias. It will be noted that nothing is here said of Hall's *graphica* of the Portage which lies flat on the bed plates and must therefore be some sort of sea plant (*Fucoides*); besides having a shape not at all suggestive of animal operation of any kind. Those


CLXXVII
No. VIII f, Portage Sandstone. Fossils.
Goniatites sinuosus. Hall.
VIII. f.
Hall. 106. 6.
Cardiomorpha sub orbicularis
VIII f
Avicula speciosa.
VIII f.
H. 106. 1.
VIII f
Cardiola vetusta.
VIII f
Cardiomorpha subtextilis.
VIII. f.
H.
Lucina retusa
VIII. f
Pterinopecten ? atticus.
H. S. Will
VIII f.
Lunulicardium ornatum
VIII. f.
Hall.
106.
Lunulicardium* acutirostrum
VIII. f.
Hall.
No. VIII g, Chemung Shale. Fossils.
Archæopteris, halliana. (Sphenopteris laxa.
VIII. g.
127. 1.
Hall.
Lepidodendron chemungense. (Sigillaria chemungensis.)
VIII. g.
127. 2. H
VIII. g. R. 677.
Filicites —— ? Hall,
VIII. g.
125.
Hall.

Crinoids are practically unknown in the *Portage formation.* It was an age of seaweeds ; and almost nothing else was entombed in the sea sands and muds of the time, at least towards the west. But here and there, in limited localities, and under circumstances of which we are profoundly ignorant—perhaps at spots where the water was more shallow than elsewhere, or in some way protected from disturbance—*colonies of stone lilies*, *Cyathocrinus ornatissimus*, Hall, (see Fig. at bottom of Plate CLXXVI), fixed themselves and built up their long slender columns of little limestone joints, held together by soft fleshy tissue. A central thread of marrow passed through holes in the discs or buttons of the stalk, from its root to the cuplike body of the animal at its top. Waving in the water on this flexible stem, like a lily on its stalk, the creature enjoyed its life in company with its mates. A multitude of long slender tapering arms, each one a miniature of the stem, but set with little branches, and these all delicately fringed like the pen feathers of a bird, waved about in the sea current, inviting, arresting and collecting food. (See Plate CLXXVI).*

The fossil shells of the Gardeau and Portage subdivisions, which do not occur in the Cashaqua (or top Genesee) are :—*Spirifera lævis* (smooth) *without ribs*, but with

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who are interested in this subject will do well to read the curious description of modern African worm burrow casts in Amer. Naturalist for March, 1892, p. 258. (see Fig. at top of plate CLXXVI).

*The existence of these little banks of stone lilies would not have been suspected but for the accidental exposure of one of them in the bluffs on the shore of Lake Erie, where the waves had eaten away the edges of the horizontal layers of rock, toppled down the mass of crinoids, and scattered their little discs along the beach to the mouth of Eighteen Mile creek. Judging by the number of heads several hundred individuals must have grown here on a spot not more than ten feet in diameter. What destroyed the little grove of animals is of course a mystery ; but they were all thrown down together, making a layer of fragments about six inches thick in the middle, thinning away all round, and were then covered with a deposit of sea mud (Hall, 1843, p. 247). Of course the revelation of one such colony is a prediction that others will be discovered ; and a good ground for supposing that many such exist under western Pennsylvania and western New York ; outliers of the great crinoidal fields of the western states, or survivals of those which flourished in earlier times.

a very deep middle groove;* *Orthis tenuistriatus* (fine-lined) a small shell found on Crooked lake; *Lucina retrusa* (blunt), *Nucula lineolata* (lined), very small; *Cardiomorpha* (*Astarte*) *subtextilis*; the last three lamellibranchs found on the Lake Erie shore. Also, the three little gasteropods: *Bellerophon striatus*, Phillips, an English species; *Goniatites bicostatus* (two ribbed) a beautiful globular whorled shell not an inch large; and the Cashaqua *Goniatites sinuosus* already mentioned. (See figures of these species on plate CLXXVI and CLXXVII above).

Conditions of Portage deposits.

The abundance of seaweed and the variety of shells testify to the rapid infilling with sandy mud of a tranquil shallow sea traversed by steady broad currents. Diagonal lamination, or *false bedding*, a common phenomenon in the flagstone beds adds its evidence. *Ripple marks* are abundant in the sandy shale, so irregular as to suggest the action of a "chopped sea," where currents and winds were opposed; or of an "undertow" on soundings. Prof. Hall suggests an alternation of deeper and shallower water; for no ripple marks are to be seen on the dark and green mud shales. *Shrinkage cracks* on the upper surfaces of the black shale, copied in relief on the under surfaces of overlying flagstone layers, prove almost beyond a doubt that the Portage sea bottom was here and there exposed to the air and sunshine and then again overflowed.

Concretions of many forms scattered through the shales show that lime-water was poured by rivers into the Portage sea; those most perfectly round lie in the slaty black shale; the flatter lens-shaped ones in the greenish black and green shales, which have no slaty lamination, but crumble into irregular pieces; the round ones have more lime and show seams of calcite.†

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*This is the only Spirifer in New York rocks of any age which has no ribs, and strangely enough seems to be confined to the Seneca and Cayuga lake region; and much larger individuals are found than that figured in Hall's Geol. 4th dist. 1843, p. 245.

† Thousands of flattened concretions fall from the bluffs and strew the shore of Lake Erie, some of them 2′ or 3′ in diameter and six inches thick,

The *cone-in-cone* structure of the concretions penetrates from the surface inward only one or two inches. The same structure is seen in wedge-shaped layers; the cones being often in concretive laminæ, transversely wrinkled, and also scratched lengthwise. (See Hall's figure, 1843, p. 232, and in my Dict. Fossils, Vol. 1, p. 138).

Mud-flow marks, not to be described but by a figure, more resembling the cooled cinder from an iron furnace than anything else, occur on shaly sandstone layers, with a thin coating of shaly matter upon the surface. There is a variety of forms; some looking like mudcasts in hollows; and some go with oblique bedding. *Mud-furrow casts*, projecting from the under-side of flagstone beds, are numerous. Their fineness, straightness and sharpness are unaccountable on the supposition of fluid motion over soft mud, especially when two sets of them cross each other. They occur at all stages or horizons of the formation, and seem to be a common accompaniment of its method of deposit. If they were made by the insects of the sea their authors are still unknown, nor can any mode of animal perambulation be imagined which would leave such records. They would most resemble casts of those glacial scratches which cover the surfaces of bare rocks or any polished rock-bed on which the northern drift reposes; but no condition of the ancient sea bottom is conceivable which would allow of ice to groove it thus. They remain one of the puzzles of nature.* (See Hall's figures, 1843, p. 253).

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and are burned for lime between Dunkirk and Portland harbor. Prof. Hall found one round ball in black shale at Sturgeon Point six feet in diameter. On the Genesee river many have the size and shape of loaves of bread. (Hall, 1843, p. 229).

* Prof. Hall notes that the direction of the ridges is nearly east and west subject to a few degrees' variation; a general direction prevailing over wide areas. Some of the furrows appear to have been made in mud partially hardened, and then the cast exhibits apparently a tremulous motion in the body making the furrow; which furnishes a suggestion of animal tracks such as those described by Prof. Nathorst of Sweden. Some of the groove casts have sharp angles as if made with a point; others rounded as if made by a smooth body, and the edges of the mud groove partly flowing together before the succeeding sand was laid upon them. In one remarkable case, a dark-colored clay-sandstone resting on black sandy shale striated was ap-

Pulpit rocks are frequently left standing along the upper line of the Portage cliffs, produced in the same way, by cleavage and erosion combined, as the Oriskany pulpit rocks described in a preceding chapter.

Calcite, *Barytes*, and *Pyrites*, with its resulting secondary product *Gypsum*, are the only minerals found in the formation, and that in exceedingly small quantities, the Gypsum merely coating the shaly laminæ or filling seams and joints with minute crystals. A kind of *coal* in seams half an inch thick frequently separates the black shales. The larger vegetables are sometimes coated with a thin film of coal; but true coal beds do not exist.—The mineral character of the formation is indicated also by a soil which betrays a deficiency of lime. A different growth of timber marks the belt of outcrop. When cleared, wheat is not sure after a few years of cultivation. The soil alluded to is that of the high lands only partially covered by the glacial drift which fills the valleys.

VIII f, Portage in Pennsylvania.

As this is the first of the Palæozoic formations which crops out in the lake district of northwestern Pennsylvania and in line with the early and exhaustive studies of it in New York, and as it gradually changes its character towards the Atlantic so that it becomes almost impossible to distinguish it from the overlying Chemung formation, I

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parently identified by Prof. Hall in another exposure twenty miles distant and similarly marked; the two localities being, one at Goodwin's Falls, the other near the head of Seneca Lake. If this identification be correct the cause of the striation operated very uniformly and over large areas. In a country so entirely undisturbed lateral movements cannot be imagined causing the strata to slide upon one another; therefore the scratches cannot be referred to the class of slickensides; not taking into account the fact that some of the grooves with a uniform direction are so large as not to permit of such an origin. Some of the ridges are traceable only a few feet, one end being large and gradually disappearing as if the furrowing body was lifted out of it. Some of these larger furrows must have remained for a time uncovered, since they are now more or less filled with the drifted fragments of shells as represented by Fig. 103 in Hall's Report, 1843, page 237. All the shells here are single valves which appear to have been quietly floated along over the even surface till lodged in the groove, and they now cover the surface of the cast of it.

shall reverse the order of description which I have pursued respecting the earlier formations, and describe it from northwest to southeast.

VIII f, Portage in Erie county.

The Portage formation along the south shore of Lake Erie presents at the New York state line nearly 500′ of its upper part above water level. Sinking southwestward very slowly, its strata disappear one after the other beneath the lake, until the topmost become submerged about two miles from the Ohio state line. Its finest exposure occurs in Northeast township along Twenty Mile creek. Where the creek crosses the state line three miles from the lake, and the Girard shale is seen overlying the Portage flags, the creek rushes down through a gorge, at the rate of between 100′ and 150′ per mile, between perpendicular cliffs more than 100′ high. This gorge or "gulf" is a famous pleasure resort.

On Sixteen Mile creek the top of the *Portage* goes under water at 925′ A. T. At the mouth of the creek at Childs' Mill the following section may be seen: Top sandstone, hard, flaggy, 10′; shale sandy, 10′; shale dark blue, fissile, 20′; sand layer, calcareous, 8″; sandstone, flaggy, 5′; concealed to lake level, 5′; total 50′ 8.″ Copious calybeate springs issue from the top sandstone, staining the rocks below a deep red and depositing bog ore in many places along the outcrop, one-fourth of a mile back from the mill-dam which is built upon it.—The limestone is very sandy, and contains some clay ironstone balls.—The sandstone under it shows curious horse-shoe *seaweeds* 2½″ from point to point, in great quantities. *Fucoides graphica* are also numerous (White, Q4, 300.)—On Twelve Mile creek the Portage flags are constantly in view, alternate shales and flaggy sandstones in which nothing can be found but *seaweeds*. Top, 905′ A. T.—In Harbor Creek township, the Portage outcrop is two miles wide. At the mouth of Elliott's run are seen very pyritiferous shales containing thin sandy layers 25′; under them grayish-green shales (5′ to the lake level) containing black streaks (a fraction of an inch in thickness) running out to nothing horizontally. From this up the run to 250′ above lake level (825′ A. T.) are seen bluish-shales and thin flaggy sandstones, overlaid by *Girard shale.* Allowing for dip, we have here 300′ of Portage in which not a single animal fossil can be discovered; but abounding in seaweeds, rain-drop casts, ripple marks, and the remarkable flowing-mud described by Prof. Hall. (Q4,294).

VIII f. Portage Oil and Gas.

In Mill Creek township, at Crowley's quarry, mouth of Four Mile run, a sandstone bed 2½′ thick is wrought; a bluish-gray rock, smelling strongly of petroleum, and used for cellar walls in Erie. Underneath it lie 20′ of shales abounding in *cone-in-cone* structure, 10′ above lake level. Another quarry, 65′ above the lake, works 3′ of bluish-gray sandstone full of *oil* and *gas.*

Gas veins are frequently struck by the quarrymen in stripping off the 6′ or 8′ of blue shale which lies upon the sandstone. The *Portage shales* are often seen forced up in ridges with opposite angles of say 30°, and fractured along the crest, apparently by sudden escape of rock-gas seeking exit toward the ravines. The gas being under high pressure the stripping off of superincumbent weight is sufficient to cause slight explosions. Top of Portage here 855′ A. T.—On Neely's Run, two miles east of Erie (a quarter of mile south of the lake, and 25′ above it), a bluish-gray sandstone (3′) in three layers, smelling of petroleum, is quarried, and the quarrymen state that they frequently find heavy oil under the lowest course of stone.

At Erie, many *gas wells* have been drilled, but few records kept. One of them, and perhaps the deepest (bored by the Stearne Manufacturing Company) avails for measurement of the thickness of the Portage formation here. Commencing at 655′ A. T. (120′ below the top of the Portage) it goes down through "gray flags" 458′; then "reddish-brown shales" 50′?* "soapstone and shales" 910′? to

* The heaviest flow of gas came out near the base of the reddish-brown shale, which was hesitatingly reported as 50′ thick. Another well at Stearne's got gas at the same depth, 500′.

763′ *below tide.* The soapstone, with occasional thin "shells" (sandy layers 1′ to 2′ thick) seems to be persistent for 1000′, excepting a few thin streaks of black slate of no importance; from which we conclude that the *bottom of the Portage* was not reached; and that its total thickness must *exceed* 1538′; which is greater than the probable thickness assigned to it by Prof. Hall along the lake in New York state. *Rock gas* seems to pervade at least the upper half of the *Portage* formation. The Cawthrow well-record states its first gas at 242′; its second gas at 271′; its third at 304′; fourth at 368′; first oil show at 392′; fifth gas at 397′; sixth at 403′; seventh at 420′; eighth at 444′; ninth at 446′; tenth at 449′; gas and oil at 468′; gas and oil at 593′; oil at 646′; bottom of hole, 695′. The rock was apparently the same gray shales (with occasional thin hard crust) throughout. Mouth of well (678′ A. T. equal 100′ above lake) 100′ below the *top of the Portage.*

Near the south line of the borough of Erie, on Mill creek, the Hopedale Mills well started 20′ below the *top of the Portage*, and got its gas vein at 650′, which, allowing for dip, would agree with the 500′ gas in the other wells. There seems, therefore, to be (in this little district at least) *a rock-gas horizon in the Portage formation at about 650′ from its top.**

In Fairview township, near the mouth of Walnut creek, 10′ above lake level, two sandstone layers, 12″ and 6″ thick, separated by 3′ of shale, hard bluish-gray, fine-grained, are quarried; bed planes covered with *fucoids* mostly cylindrical. Another large quarry (Davidson's) 400 yards above the road, up the creek, works 5′ of sandstone in several layers, sometimes running together and becoming

* From this horizon came the great gas strike of the Bell's well at the Point (Q4, 291).—Over the city of Erie the *top of the Portage* would be by calculation 220′ in the air. As it sinks to water level at Raccoon creek, 20 miles west of Erie, the dip along the coast must be *10′ per mile* (Q4, 287–8). For discussion of dips of formations in Erie county see Q4, 51.—At Oliver and Bacon's canal mills a splendid strike of gas was made at 470′.—Is the Bradford oil then of Portage age? This interesting question cannot be answered with certainty; but if it could, the vegetable origin of petroleum in the very rocks in which it lies would be placed almost beyond the reach of adverse criticism.

massive. *Plant fragments* in great abundance are seen in the rock which smells strongly of petroleum, the oil floating out from the bottom courses when lifted. The *plant species* cannot be made out, but some of them were evidently branches of large trees. Some are covered with thin films of coaly matter. The top-flags up the creek reach 718′ (127′ above lake level); and then vertical cliffs of Girard shale rise on both sides of the ravine.—Bear's creek cuts down through a succession of thin sand-layers separated by blue shales.—At Trout run mouth, 10′ of sandy shale above lake level cover a submerged sandstone stratum 1′ thick, large blocks of which thrown up by the waves are used for buildings; when the lake level is lower than ordinary the bed is quarried, a hard bluish-gray rock covered with fossil seaweeds. An oil well here went down 700′ through blue "soapstone" with an occasional hard streak all the way, except near the bottom streaks of dark slate (2″ or 3″) were passed; and at 350′ down a great gas vein.—Luther's well struck a big gas vein at 500′. In Girard township, on Elk creek, Ealy's quarry worked the extreme top sandstone layer of the Portage series underlying *Girard* shales. It is a hard, blue, fine-grained sandstone, not quite 1′ thick, covered with fossil seaweeds, 635′ A. T. (62′ above lake level).—Godfrey's quarry works lower layers of Portage flags at water level one mile below Girard Bridge.—In Springfield township the Portage disappears beneath the lake.

VIII f. Portage in Middle Pennsylvania.

Along the Allegheny mountain escarpment the Portage formation makes the lowest terrace for a hundred miles through Bedford, Blair, Centre, Clinton and Lycoming counties.—It makes the long lines of rounded foot-hills in front of the Allegheny mountain, on the last slope of one of which Altoona is built. The outcrop is beautifully sculptured along its whole line by short and gentle ravines descending from the mountain across the basset-edge of the strata; the dip bearing northwestward at angles varying from 20° to 30°. Many of the layers are olive colored; some of them weathering to bright yellow, green, and red; and abounding (locally) in fossil shells.

In Blair county, it is difficult to separate it from the Chemung above; but it rests distinctively upon the gray and black slates of the Genesee beneath; and may be summarized in the following section:—

Portage slate and sandstone, both gray, ...	418
" slaty sandstone and gray slate, ...	75
" sandstone, gray, ...	10
" slate, gray, some beds with ripple marks, . . .	100
" sandstone, slaty and thin-bedded, gray, . . .	600=1203′

The Portage rocks make also the little triangular hill country in the center of the Frankstown cove, through which the Juniata river flows from Hollidaysburg past Frankstown to Williamsburg. Here, near Frankstown, they are exposed with a thickness of about 1200′ as a series of moderately thin fine-grained dark-gray sandstone beds alternating from top to bottom with thin beds of blue clay-shale. If any difference exists it is in a predominance of flagstones toward the middle of the mass. A few large *seaweeds* may be found on careful search; and a small species of *Nucula* is occassionally seen. (Rogers Geolo. Penn. 1858, Vol. I, page 540).

In Centre county, Worth township, the Portage flags, thin sandstones, and shale beds are seen well up on the hillside above S. Hoover's, dipping 30° (N. W.), forming a series of low terrace hills (T4, 270).—In Union township, they are equally visible but not distinguishable from the *Chemung*.—In Boggs township, north of an exposure of *Genesee* black slates, the lowest *Portage* flags and sandstones, green, yellow and iron-stained, crop out along the road near D. Watson's dipping 30° (N. W.).—In Howard township, they can be examined on any of the streams descending from the mountain, as low cliffs capped by *Chemung* rocks.—In Liberty township, an excellent exposure of *Portage flags* can be studied at Thompson's, dipping 20°, N. W. (T4, page 298).—In general terms it may be said that in this Bald Eagle valley, the line of division between the *Portage* and *Genesee* outcrops runs about three-quarters of a mile back from or northwest of the railroad; and although the line of division is not well marked, the shales above the *Genesee* become flatter, more sandy, and more of a Chemung character.*

In Clinton county the Portage-Chemung mass is magnificently exposed along the Susquehanna West Branch above Lock Haven by railroad cuttings; but as the rocks consist of alternate gray sandstone, olive and gray shales and slates, with an occasional layer of red or purple slate or sandstone, through a total thickness of 3314 feet, it is impossible to draw a distinction between *Portage* and *Chemung;* therefore a section of the whole will be given in the chapters on the Chemung (G4, 105).—From Lock Haven eastward to Emporium, what should be the outcrop of the Portage is concealed beneath the river bottoms; but on Pine creek in Lycoming county a section of Chemung and Portage combined seems to measure more than 3000 feet, but with contorted strata and imperfect exposures (G2, 41).

VIIIf Portage in Bedford and Fulton.

From the Aughwick Valley in southern Huntingdon the *Portage outcrop* runs (north northeast) through Hare's valley, between Jack's Mountain and Sidling hill, to the Juniata at Mapleton and Mill Creek; thence up Mill Creek valley west of Standing Stone mountain to the Barre township line; thence back (southwest) along Stone Ridge to the Juniata river below Huntingdon; and so continuously (southwest) along Piney Ridge into Bedford county. The river makes a gap through the formation walled in by bluffs on both sides.

The combined thickness of *Chemung and Portage* is estimated by Prof. White at 2650 feet; being roughly divided into (1) an upper, more massive, gray sandstone *Che-*

* Back of Unionville lie in considerable numbers very large boulders of a coarse or conglomerate sandstone somewhat resembling the Oriskany. The rock is probably in the *Portage* formation; and above it are seen sandy shales (olive, drab, and red) with sandstones; in the lower part of which (within a mile of Juliana) may be collected *Cyrtina hamiltonensis*, a *Productella*, and *Spirifero mucronata.* This, so far as fossils are a test, leaves it questionable whether we are in *Chemung* or *Hamilton.* But higher up the *Chemung* fossils are unmistakable (Ewing, T, 433).

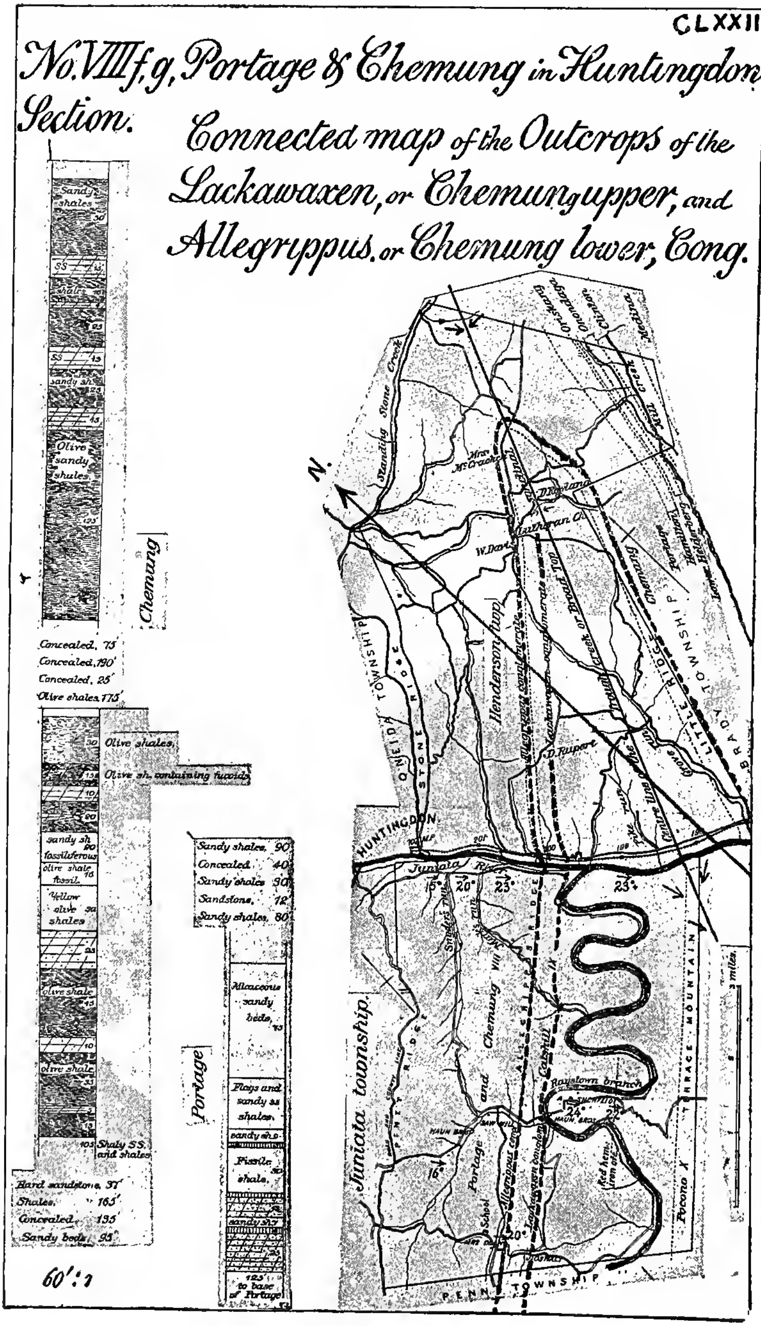
mung division 1500′ to 1600′ and (2) a lower yellowish, sandy shale and shaly sandstone *Portage* division, 1000′ to 1100′; the *Chemung* making the higher ridges; and the *Portage* making (where the dip is gentle) wide and nearly level slopes of farm land with a yellowish poor soil. But the strata at the bottom of the *Portage* being rather harder than the rest of the formation, the surface suddenly falls off with a steep pitch into the *Hamilton* and *Genesee* valley. Huntingdon is built on a *Hamilton* plain; vertical bluffs of the lower *Portage* sandstone rising from it along the edge of Standing Stone and Muddy creeks; and behind and overtopping all, the *Chemung* ridges; the highest crest of which is called Allegrippus ridge.—Not a single red bed was detected anywhere in this district (including Bedford and Fulton) in either the *Chemung* or in the *Portage*, i. e. beneath the *Allegrippus conglomerate* which lies near the top of the Chemung (T3, 99).

In Fulton county, Prof. Stevenson found no difficulty in recognizing a marked distinction between the *Chemung* (upper) and *Portage* (lower) divisions of 3620 feet of strata. But in Bedford county no such distinction could be made out; therefore throughout his report he has discussed the whole mass under the name of *Chemung*.

In Fulton county, the principal divisions may be summarized thus:—

Chemung	shales with occasional beds of sandstone,	800	
"	sandstone with layers of conglomerate,	10	
"	shales and sandstones,	950	
"	sandstone with conglomerate layers,	10	
"	shales,	450=2220′	
Portage flags,*			1400′

* These are well shown on the Bedford pike east from Licking creek. They make the side slopes of Timber Ridge. They are well shown on Tonoloway creek, at and below Franklin Mills in Bethel township. On the freshly broken surface the rock is generally olive or grayish-olive; but the old weathered surfaces are dingy, covered with a grayish lichen, and strikingly resemble the Catskill sandstone. Separating shales are in comparatively small quantity; and they are sandy enough to resist the weather almost as well as the flagstones; consequently the formation makes bold cliffs in many places.—No characteristic Portage fossils have been found. Such of the beds as contain fossils contain only those which are (in New York) characteristically Chemung; but, owing to their condition, their generic name only can be given, but not the species (T2, 77).


CLXXII
No. VIII f. g, Portage & Chemung in Huntingdon.
Section.
Connected map of the Outcrops of the Lackawaxen, or Chemung upper, and Allegrippus, or Chemung lower, Cong.
Sandy shales
Olive sandy shales
Chemung
Concealed, 75'
Concealed, 190'
Concealed, 25'
Olive shales 175'
Olive shales
Olive sh. containing fucoids
sandy sh. fossiliferous
Yellow olive shales
olive shale
Shaly SS. and shales
Hard sandstone, 37'
Shales, 165'
Concealed, 135'
Sandy beds, 95'
60' : 1
Sandy shales, 90
Concealed, 40
Sandy shales, 30
Sandstone, 12
Sandy shales, 80
Argillaceous sandy beds
Flags and sandy shales
Fissile shale
Portage
to base of Portage
N.
Standing Stone Creek
Mill Creek
Juniata River
HUNTINGDON
ONEIDA TOWNSHIP
STONE RIDGE
LITTLE TOWNSHIP
BRADY
Henderson twp.
Juniata township.
PENN TOWNSHIP
TERRACE MOUNTAIN
Raystown branch
D. Rupert
W. Davis
Lutheran Ch.
Chemung
Portage
Hamilton
Medina
Clinton
Oriskany
Onondaga
Catskill
Pocono X
3 miles

In Bedford county, where the *Chemung* and *Portage* mass is almost 3000 feet thick,* 1100 feet of it at the bottom are exposed at Saxton, as follows:—

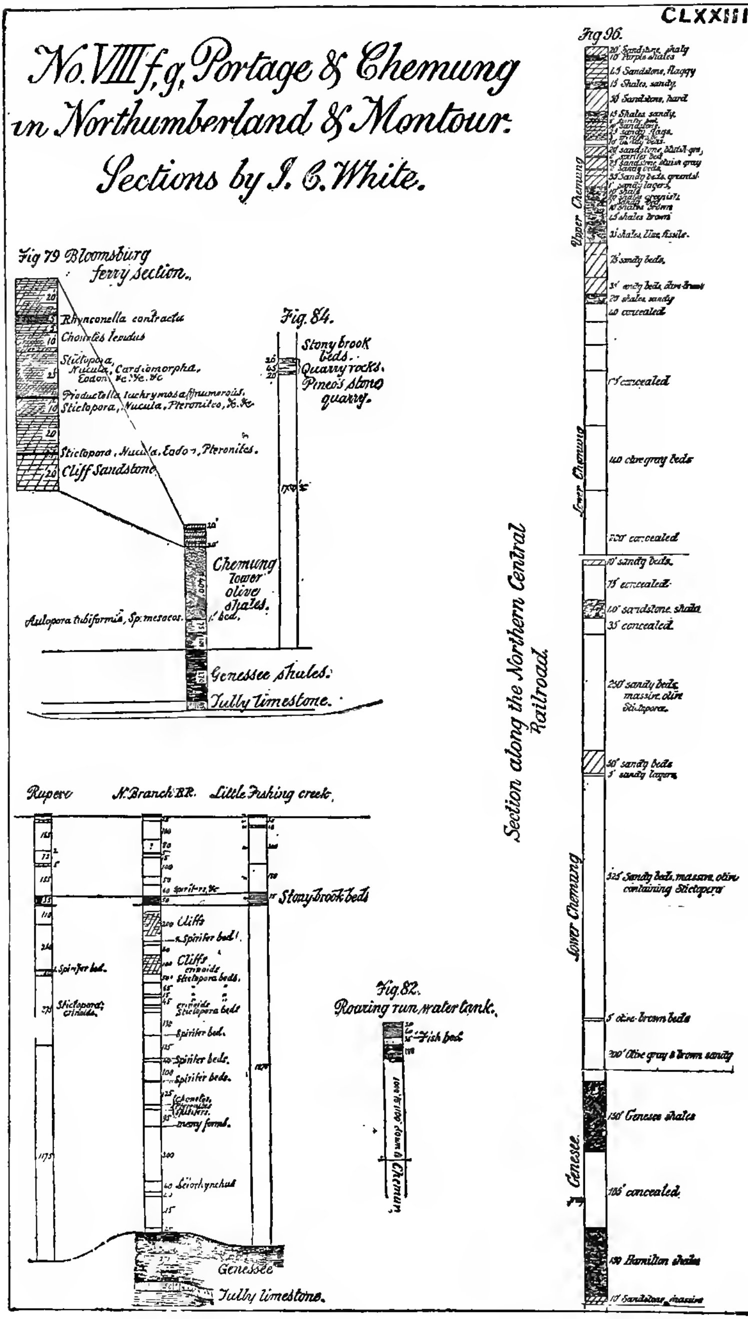
Portage	flags and shales,	250
"	sandstone,	105
"	variegated shale,	523
"	concealed,	58
"	shale with irregular flaggy sandstone,	82
"	shales and flags,	102=1120′

By comparing the two detailed sections in the two counties it will be seen how they differ, flags predominate in Fulton, and shales in Bedford. Moreover, in Fulton *Chemung fossils* occur at only a few horizons in the flags; whereas in Bedford they are found at many horizons, down to within less than 300′ of the bottom. *No Portage fossils were found anywhere in either of the two counties.*—The whole series shows a noteworthy decrease in thickness in Bedford county westward; for, on Wills' creek (where, however, no exposures are visible) the interval occupied by *Chemung*, *Portage* and *Hamilton* together is about 2630′. All these considerations will be reviewed in detail in the chapters on the Chemung formation.

VIII f, Portage in Huntingdon county.

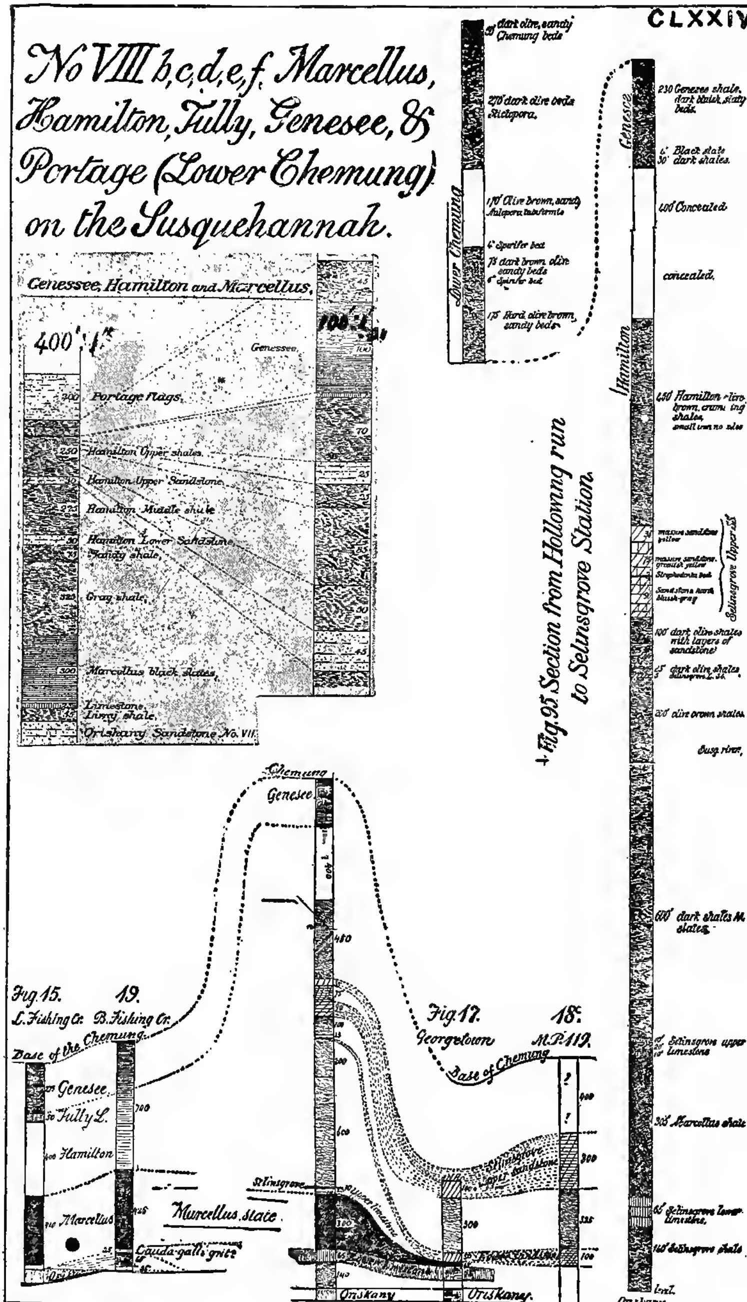
On the Juniata in the Lewistown valley, no rocks remain higher in the series than the *Marcellus* until we pass westward into Huntingdon county. Here a total thickness of 3400 feet of strata from the *Genesee* upward was meas-

*The measurement given on T2, 77, are 500, 211, 1047, 116, 165, 203, equaling 2242; but a reduction to at least one-half must be made for dip. Moreover there is a concealed interval above, and another below, so that the actual thickness of this part of the section must be at least 1100 feet, and may amount to 100 or 200 feet more.—On the Yellow creek, the same series measures about 1360 feet.—In the concealed interval above the section is much yellow shale, some of the beds being fossiliferous. The division between *Chemung* and *Portage* would be made at the top of the section by working westward from Fulton county into Bedford. The sandstone, however, under the flags and shales contains *Chemung fossils.* It also contains *seaweeds*; but they are not numerous. The variegated shale is fairly well exposed on the Huntingdon railroad and Pittsburgh pike and contains in its upper part *Chemung fossils*; flagstones predominating toward the top; and being scanty below. The lowest 200′ of the section is mostly olive flags and shales, without fossils.


CLXXIII
No. VIII f, g, Portage & Chemung in Northumberland & Montour.
Sections by I. C. White.
Fig 79 Bloomsburg ferry section.
Rhynconella contracta
Chonetes lepidus
Cliff Sandstone
Chemung lower olive shales.
Aulopora tubiformis, Sp. mesacos.
Genessee shales.
Tully limestone.
Fig. 84.
Stony brook beds.
Quarry rocks.
Pineo's stone quarry.
Rupert
N. Branch R.R.
Little Fishing creek
Stony brook beds
Cliffs
Spirifer bed.
Stictopora beds.
Leiorhynchus
Genessee
Tully limestone.
Fig. 82.
Roaring run water tank.
Fish bed
Section along the Northern Central Railroad.
Fig 96.
Upper Chemung
Lower Chemung
Genesee.
150' Genesee shales
105' concealed
150 Hamilton shales
10' Sandstone, massive

ured along the East Broad Top railroad by Messrs. Ashburner and Billin (F, 221), and subdivided perhaps arbitrarily into three, viz.: at the top 90 feet of *Catskill-Chemung* transition beds; in the middle, 1860′ of *Chemung* beds; at the bottom, 1450′ of *Portage* beds. The general character of the so-called *Portage* beds seems the same throughout. The upper strata are rather massive, brown, and gray sandstone, alternating with beds of olive and gray shale, from ten to thirty feet thick. Toward the center the sandstones becomes more flaggy and thinner, while the shales become thicker, more clayey, and more various in color. As we approach the bottom the sandstones becomes thinly laminated in beds but a few inches thick; the shales weathering into mere clay. Throughout the whole, from top to bottom, the shales contain more or less iron which washes out and is oxidized, coloring the outcrops to various shades of yellow, brown and red.

In the Aughwick valley, around the end of Jack's mountain these strata are turned up at angles of 30° and 40°, and behind the mountains nearly to the vertical; consequently there is no comparison between the ease of examining the surfaces of the beds here and in western New York. When therefore it is asserted that cross-lamination or current-bedding, ripple marks, etc. which are so abundant in the *Portage* of New York are not to be found in southern Huntingdon the statement must be received with some hesitation; but so far as it is true it would cast a doubt upon the *Portage* character of the rocks. Concretions and beds of limestone are however also apparently wanting. As for ripple marks they could hardly be overlooked if abundant; as may be easily seen from the fine exposures of them noticeable along the railroad in the transition layers at the top of the *Chemung;* in the lower *Catskill* in Smith's valley; and at the bottom of the *Hamilton* near Potts' Gap. The absence of limestone or lime-shales and of lime-concretions has been attributed to a lack of marine life; but that is putting the cart before the horse, the effect before the cause. The true statement is that in Huntingdon county the whole mass of rock lacks lime-cement; the


CLXXIV
No VIII b, c, d, e, f. Marcellus, Hamilton, Tully, Genesee, & Portage (Lower Chemung) on the Susquehannah.
Genessee, Hamilton and Marcellus.
400' 4"
Genessee.
Portage flags.
Hamilton Upper shales.
Hamilton Upper Sandstone.
Hamilton Middle shale.
Hamilton Lower Sandstone.
Sandy shale.
Gray shale.
Marcellus black slates.
Limestone.
Limy shale.
Oriskany Sandstone No. VII.
Lower Chemung
dark olive, sandy Chemung beds
270' dark olive beds Stictopora.
170' Olive brown, sandy
4' Spirifer bed
75' dark brown olive sandy beds
175' Hard olive brown, sandy beds.
Genesee
230 Genesee shale, dark bluish, slaty beds.
6' Black slate
30' dark shales.
400' Concealed.
concealed.
Hamilton
450 Hamilton olive brown, crumbling shales,
100' dark olive shales with layers of sandstone.
200' olive brown shales.
Susq. river,
600' dark shales & slates.
Selinsgrove upper limestone
305' Marcellus shale
65' Selinsgrove Lower limestone.
140' Selinsgrove shale
Oriskany
Fig. 95 Section from Hollowing run to Selinsgrove Station.
Chemung
Genesee
Fig. 15. L. Fishing Cr.
19. B. Fishing Cr.
Base of the Chemung.
Genesee.
Tully L.
Hamilton
Marcellus
Marcellus slate.
Cauda-galli grit
Selinsgrove
Oriskany
Fig. 17. Georgetown
18. M.P. 119.
Base of Chemung
Selinsgrove upper sandstone
Oriskany.

sea was poor in lime water and bred no shells. This explains another fact, that not only the shales but even the bastard limestone beds in the railroad cuts weather down with great rapidity (F, 227).

VIII f, Portage in Perry county.

On the lower Juniata in Perry county the *Portage-Chemung* interval varies in thickness from 3800′ (3300′?) at Newport to 1100′ in Rye township on the Susquehanna at Marysville. How much of this should be considered *Portage* there seems no mode of determining; nor is it a matter of any great importance. So far as fossil species can settle such a question the whole of it may be called Chemung. But at the very bottom of the mass or rather underlying it are about 200 feet of coarse black shales in which *Portage species** occur in sufficient abundance at most of the localities where their outcrops is exposed to view. But the commonest and most characteristic shell among them is in New York both a *Portage* and a *Genesee* species, *Cardiola* (*Avicula*) *speciosa*.† Considering the thinness of the *Genesee* in Perry county (200′) and the black color of these shales, it seems more reasonable to assign them as an upper division to the *Genesee* and look for the *Portage* among the Chemung strata overlying them. But it is useless to do this as there seems to be no criterion at hand.‡

In Centre township *Portage shale* was recognized only near the house of S. Brown, where its outcrop at the roadside contains the characteristic fossils (See Proceedings of the American Philosophical Society for 1883; also F2, 207).—In Miller township, the Genesee and Portage range along the north side of the upper road of Baileysburg in the low ground; and along another line south of Mahanoy

* Some of them apparently new. Claypole, F2, p. 69.

† Hall, Pal. N. Y. V. 1877.—Report 1843, p. 243.—S. A Miller changes most of the *Cardiola* species into *Panenka* species; but he leaves Hall's *C. speciosa* unchanged.

‡ In Carroll township, Portage fossils can be got near an old mill on the south side of the road a mile from Drumgold's tannery, where the shales are as usual dark, cross cleft, and of usual thickness (F2, 164).

ridge in the valley of the north branch of Losh's run (F2, 274).—In Wheatfield, the Portage shale fossils can be collected from a good exposure at the mouth of Losh's run; and at another place 1½ miles southwest (F2, 391).—In Oliver, two good outcrops of the *Cardiola shales* may be seen on the two roads leading south from Newport; on the road to Clouser works on the hill north of Ramer's house, where most of its characteristic species can be obtained; and on the upper road to Baileysburg on Langacre's land, where the top beds show, and the sandstone above them. (F2, 281).

VIII f, Portage on the N. Br. Susquehanna.

On the Susquehanna river North Branch, in Columbia and Montour counties, where the interval between the *Catskill* and the *Genesee* is nearly 2500 feet, not only is there enough room for the *Portage formation* but *Portage fossils* appear at two horizons between 600′ and 800′ above the *Genesee formation;* viz., *Cardiomorpha suborbicularis*, *Nucula lineolata*, and *Bellerophon expansus*. With these are found several *Hamilton* fossils. It is possible to regard all the beds above the *Genesee* to a height of about 1000′ as representing the *Portage formation;* but the two fossils *Leiorhynchus mesacostalis* and *Pteronites chemungensis*, which are usually regarded as characteristic of the *Chemung formation*, are found in a stratum twenty feet thick lying only 200′ above the *Genesee*. As there seems no marked difference in the character of the rocks making up this series of 3500 feet, it will be equally proper and more convenient to describe the whole of it in a following chapter on the Chemung formation.

VIII f, Portage on the Delaware.

On the Delaware river in Pike, Monroe and Carbon counties, as well as eastward towards the Hudson, and around the eastern and northern foot-slope of the Catskill mountains in New York, the Portage formation cannot be recognized as distinct from the overlying Chemung. In nearly two thousand feet of strata from the Genesee black slate upward no characteristic Portage fossil has been seen. Not a single seaweed has been found. All the shells are of Chemung type. There is a total absence of those hard blue sandstones which distinguish the Portage in New York. In fact there is no room for the formation in an interval so small between the Catskill and Genesee as 1850′ on the Delaware, 1750′ in Monroe, 1600′ on the eastern line of Carbon, and 1200′ on the Lehigh river. Any search for it must be prosecuted along the upper margin of the Genesee belt described in a previous chapter.

The antient expansion of the Portage and Chemung southward has been rather unexpectedly illustrated by the discovery of fossils of that age in some of the strata of the Green Pond mountain of northern New Jersey; conglomerates once considered to be of Mesozoic or New Red age, until in 1863 Prof. Cook found Trenton species in one of the two enclosing limestone formations, the other being still non-fossiliferous.

The Oneonta sandstone.

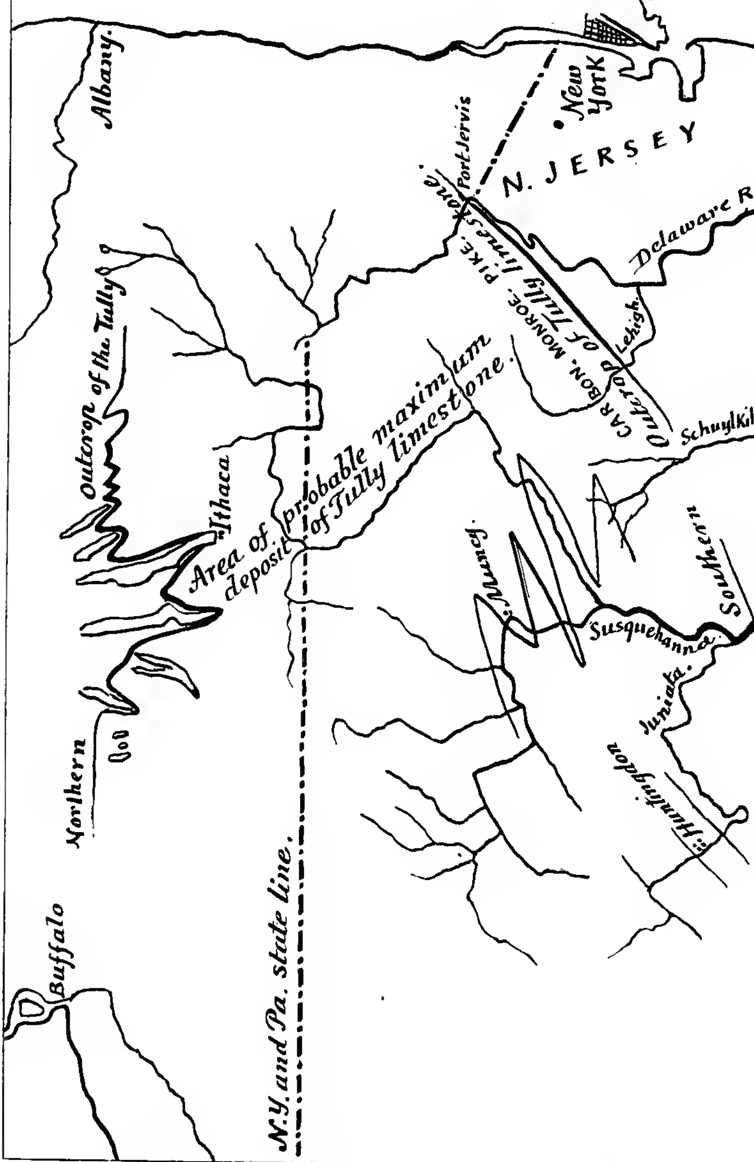
Pending the publication of Prof. Hall's last and present reexamination of this interesting and much discussed series of beds in eastern-middle New York, I may be permitted to say here that Prof. Hall's old idea that the Chemung formation thins out towards the Hudson, or at least changes its character, loses its fossils, and mingles with the Catskill, bids fair to be borne out by all the facts. (Private letter of date June 24, 1892.)

The *Oneonta sandstone beds*, instead of being at the top of the Chemung, constitute in Prof. Hall's present opinion the true base of the great Catskill formation, in fact *a Lower Catskill, deposited before the Chemung.*

But this is the horizon of the Portage. Prof. Stevenson's description of Catskill-like Portage beds in Bethel, Bedford co. Pa. is therefore very interesting.

Chapter 90. CCI.

VIII d. Sketch map of probable area of maximum deposit of Tully limestone (Cuboides zone)



CHAPTER LXXXXIII.

VIII f, g. The Girard shale of Erie county.

Prof. White in his survey of Erie county (G4) established a new subdivision of the middle Devonian system, which may be considered the upper member of the Portage formation, as Vanuxem's Ithaca formation has been accepted as nothing but a lower member of the Chemung of middle New York. The vertical column of formations given in the report on Crawford and Erie, G4, on the edge of the colored geological map of the two counties is as follows:—

XII.	Pottsville conglomerate,	245′
XI.	Mauch Chunk red shale,	50′
X.	Pocono sandstone,	227′
	Intermediate,	235′
IX.	Venango oil sand group,	310′
VIII g.	Chemung,	325′
	Girard shales,	225′
VIII f.	Portage—visible above the lake,	475′

The description of the Girard and Portage shales which he gives with the column will be the best introduction to the subject, showing the two :—*Girard;* ashen grey shale, quite homogeneous throughout, with very few gritty layers; totally destitute of animal remains; constituting a transition series between Portage and Chemung.—*Portage;* grey shales alternating with thin hard sandstone beds; destitute of fossil life except Fucoids (sea weeds). Its top rises from Lake Erie 2 miles east of the Ohio state line and rises regularly eastward to 475′ above the lake water level at the New York state line, its lower beds still remaining beneath water level, and continuing to rise in the state of New York. In Report Q4 he thus describes it.

The *Girard shale* in Erie county, Pa., overlies the *Portage* outcrops along the slope of the high land facing the lake, presenting vertical cliffs on each side of every stream which descends to it.—Its thickness, 225′, as fixed by several direct vertical measurements, seems to be constant across the county from the New York to the Ohio state lines ; but owing to the greater steepness and height of the high land slope at the east than at the west the breadth of its outcrop on the New York line is scarcely half a mile, but on the Ohio line at least three miles, and in Girard township extends back from the lake six miles. The thickness does not seem to vary in going southward ; for, in the boring at Oil Creek lake, in northeastern Crawford county, twenty-five miles from Lake Erie, it seems to be represented by 262′ feet of soft slate ; part of which, however, may belong either to Portage below or Chemung above.—*Fossil shells are entirely wanting ;* hundreds of exposures were carefully examined by Prof. White without finding one. The casts of *seaweeds*, however, are very abundant.

The strata consist of ashen-grey and bluish shales, with only now and then a thin layer of sand. They exhibit this finely in every ravine which descends from the great divide ; but especially along Elk creek above the village of Girard. Seen at a distance, its steep slopes or bluffs look like the boulder clay of the drift ; and it sometimes stands like vast banks of gray coal ashes. From this place it gets its name ; being exposed all along Elk creek ; remarkably uniform in its constitution and crowded with seaweeds. Very few sandy layers can be seen in the mass of finely laminated clay slate. Elk creek makes an ox-bow a mile and a half around, cutting down through the Girard shale between perpendicular cliffs more than 100′ high, enclosing the Devil's Backbone. At Girard village the shale is seen lying on the top sandstones of the *Portage* at Ealy's quarry. Here 40′ of the shales are visible, more silicious than those above, but destitute of genuine layers of sandstone (Q4, 259).

In Fairview township at J. Ryan's the following section will show the relation of the overlying Chemung to the Girard :—

Chemung third oil sand (quarry portion),	6′
Shaly sandstone and shale (fossiliferous),	270′
Sandstone, shaly and flaggy (no fossils),	55′
Calcareous stratum,	0′6′
Girard shales, blue, to bed of Elk creek (no fossils),	50′

In this section all fossils cease at the bottom of the 270′ mass. The underlying 55′ of shales and flaggy sandstones are entirely destitute of fossils, except seaweeds. There seems to be no special reason for making the calcareous layer a plane of division except that not a single sandy layer was seen below it; only soft ashen-gray clay shales, with *seaweeds in great abundance*, and nothing else. Moreover, the calcareous band in this section corresponds to one seen at the base of the Chemung flags in middle Pennsylvania.*

The distinction between the *Girard shales* and the *Portage flags* (under them) is purely one of mineral constitution, founded on the relative proportion of sand deposits in the two formations. Both are equally bestitute of animal life; and both are characteristically crowded with marine vegetable impressions; while in contrast to these, the overlying *Chemung* strata are abundantly supplied with fossil shells of various genera and species, increasing in numbers upward and becoming exceedingly numerous in the upper half. It seems, therefore, reasonable to throw the *Girard* and *Portage* together; but the *Girard* can be considered as a separate formation; or as a transition group; or as the lower member of the *Chemung*, as individual geologists may prefer. In New York state, no division like that of the *Girard* has been recognized. If the top of the *Portage* in New York were an established and definite plane, the *Girard shale* might, by careful comparison of localities, be

* The cliffs of *Girard shale* extend up Elk creek ten miles to the McKean township line; and in the side ravines on Struker's branch, its top is at water level at 890 A. T.—In Mill creek township, along Mill creek, the Girard shale is finely exposed, its top going under the creek near Daniel Winfield's at 940′ A. T. Its base, near Hope Mills, is at 750′ A. T.; allowing 40′ for dip, 230′ thick; agreeing closely with the measured 225′ at Girard. In Harbor Creek township, on Elliot's run, the bottom of the Girard is 825′ A. T.: and its top (near Grove's) 1070′ A. T. On Six mile creek, the top goes under water near the woolen factory at 1060′ A. T.—In Northeast township, on Twelve Mile creek, the bottom of the Girard is at 905′ A. T.; its top at Mrs. Leonard's, 1125′; thickness (allowing 5′ for dip) 225′. Where the road crosses Twelve mile creek, near Huston's, the cliff of shale 50′ high shows very few sandy layers. On Sixteen Mile creek, the top of the Girard cliffs goes under the creek near Seely's mill at 1150′ A. T. The bottom, at the head of Averill run, near the state line, is seen at 980′ A. T.

recognized ; but its total destitution of molluscan life would be found not to hold good in advancing eastward from Lake Erie ; inasmuch as the whole column of *Chemung* and *Portage* in eastern New York is practically speaking fossiliferous from top to bottom ; therefore, any non-fossiliferous shaly sub-division like the *Girard* in our Erie county must necessarily vanish before the eyes of the geologist who works in eastern New York. The case seems to be the same in middle Pennsylvania. where no such sub-division as that of the *Girard shale* has as yet been recognized, at least with any distinctness ; and the distance from Lake Erie to the Appalachian outcrops on the Juniata and Susquehanna is so great (say 150 miles), and the changes of constitution in that direction in all the formations are so notable, that one may be excused for any amount of incredulity as to the plain existence of the *Girard* in that region. On the other hand, the persistence of the *Genesee* for an equal geographical distance makes it quite possible that the *Girard* might equally persist.

The *Ithaca Group* of the early New York reports received its name from the well-developed outcrop of highly fossiliferous shales and shaly sandstones at the railroad inclined plane at the head of Lake Cayuga and on Cascadilla and Fall creeks near Ithaca. It was supposed at first to be the formation overlying the *Portage* and underlying the *Chemung*; but subsequent investigations (along the Chemung river) into the highly fossiliferous lower strata of the *Chemung group* resulted in the conviction that the *Ithaca* was only a lower member of the *Chemung*, inasmuch as there were no charactenstic fossils to distinguish them ; scarcely a fossil known at *Ithaca* but was found at numerous other Chemung localities ; although at Ithaca and in many other places some of the shells were confined to single localities, that is, occurred in colonies ; and by this colonial existence their peculiarities or varieties of specific form were, so to speak, accidently and locally developed ; for a special local aboriginal creation of such characteristic forms is not acceptable to the spirit of our modern science.*

*See James Hall, 1843, page 250, on the *Ithaca Group*.

Chapter LXXXXIV.

VIII g, Chemung formation in New York, with its fossils there.

As White's Girard shale is evidently only the upper part of the Portage formation, so Vanuxem's *Ithaca group* has been taken by geologists as merely the lower part of the Chemung formation.*

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*Vanuxem, in his report of 1842 (page 174), describes the *Ithaca group* not less than 400′ thick, as a mass of hard and coarse shale and sandstone, dark in color and often brown after exposure, owing probably to manganese; the constituent layers having no particular order and their difference of constitution being too indefinite to permit the mass to be sub-divided into parts. But at McCormick's quarry, near Ithaca, a hard, tough, dark brown sandstone in irregular layers is exposed; as also at the cut on the inclined plane; and at the tunnel on Fall creek; the joints being vertical, in two directions a little east of north and a little south of east; producing on the north bank of Fall creek gigantic pilasters like those on Cayuga lake.—Fossils are numerous but not so well preserved as those in the *Chemung* strata above to the south. *Strophodonta cayuta* (*Strophemena interstrialis*, *Leptaena interstrialis* of Phillips) is abundant half-way up the inclined plane; also at Scott's Corners, near the head of Skaneateles lake; at the quarries north of Homer; was found also by Conrad and Hall at Chemung Narrows. It has a considerable vertical range, descending nearly to the top of the Genesee slate.—Another shell, *Strophomena ithacensis*, is not abundant on the incline plane. Vanuxem remarks that distinctly characteristic fossils should be sought for towards the bottom of the inclined plane; for those seen higher up are common to the *Chemung* formations; such as the *Atrypa squamosa;* an *Atrypa* like *prisco;* and a *Strophomena* like the English *membranacea* (*Productella hirsuta*).—In the lower rocks at Ithaca are three or four species of *Cypricardites;* a coiled shell like the English *Clymenia;* three or four *Atrypæ*, etc.—A curious *fern*-like fossil has been found at the inclined plane and at the tunnel; but as ferns belong to a later age this has been supected to be a sort of Crinoid (see wood-cut 46 on page 475, Vanuxem). From its stem diverge on both sides short parallel stiff thin hairs. Fossils like *land plants*, but very obscure, have been found on the inclined plane; showing no surface-markings, varying greatly in size, some more than 2′ long, by 2″ or 3″ wide, and converted into a layer of coal, occasionally exceeding one-fifth of an inch in thickness. Similar plants were found on the road to Dryden; are numerous at the Homer quarries; at Derby & Miller's quarry in Truxton; and in many other places. Some fragments show a spear-shaped or lance-shaped form. One from Truxton Corners has the shape of a reaping-hook, 8″ long, *The Chemung outcrops.*

The Chemung formation is one of the largest and most extensively exposed at the surface of the state. Its nearly horizontal northwestern outcrops issue from the high escarpment of Erie county overlooking the lake. The formation no doubt once extended to and covered Canada. It slowly sinks southward at the rate of 15 to 20 feet per mile beneath the western counties, and rises suddenly in middle Pennsylvania at the foot of the Allegheny mountains. Its top is penetrated by all the northern oil wells. Its upper gravel layers hold the petroleum of the Venango-Butler belt; its lower sands that of the Warren field; its still lower shales that of the Bradford region in McKean county, Pa. and in Allegheny county, N. Y.

The formation is so very thick and the northern outcrop dip is so gentle that the outcrop belt is many miles broad; so that it covers most of the whole southern range of counties in New York, and much of the surface of the northern range of counties in Pennsylvania from Lake Erie to the Delaware river, spreading southward up all the river valleys, the Allegheny, Genesee, Tioga, North Branch, Susquehanna and Delaware. It occupies the hill country north of the Catskill mountains; makes the foot hills of the Catskill down the Hudson river; the foot hills of southeastern New York, south of the Catskills; recrosses the Delaware above Port Jervis; makes the broad hill country between the Delaware and the foot of the Pocono mountain in Pike and Monroe; runs on past Stroudsburg to the Lehigh, Schuyl-

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covered with small deep round pits, not well defined.—*Cocktail seaweeds* (*Fucoides caudagalli*) make their appearance in these *Ithaca strata* for the third time in the history of the Palæozoic system; their first age being at the top of the *Oriskany;* and their second in the *Hamilton* formation. They have been already described and figured in the chapters of those formations. The curtain seaweeds of the *Hamilton* reappear in these *Ithaca* rocks; and are quite numerous and extremely well preserved at two places:—at Burdick's quarry east from Cayuga lake on the hill southeast of the village of DeRuyter (not very far above the *Genesee slate* in the valley below) where they occur for a considerable distance around the quarry and along the road to Smyrna. One specimen in the shape of a chemical retort is figured in Vanuxem on page 177.—A second good locality is Harris's quarry near the top of the hill west of North Norwich worked for the Chenango canal locks.

kill and Susquehanna rivers; enters Perry county, and zigzags broadly throughout middle Pennsylvania into Maryland, and so on south to the Virginia-East Tennessee line.

The Chemung limits.

From the bottom of the Portage to the top of the Chemung there is a continuous and conformable series of deposits of sands and muds; so that in Pennsylvania and most parts of New York it is a mere matter of fancy where any line between them is established by any geologist working in any part of the region; neither Girard shales nor Ithaca shales being recognizable with any definiteness between them. The two are virtually one enormously thick formation.

And if this be true of any supposed bottom limits of the Chemung it is equally true of any supposible top limits; for the deposits of Chemung sands and muds were continued without intermission or interruption into and through the later Catskill age, with only an increase of *red* sands and shales, and the occurrence of beds holding innumerable fragments of the skin-plates and bones of fishes. Palæontologists may define these formations as they please, but they will find all their efforts fruitless, and they only place their opinions in opposition to each other, each opinion being valid for the sevaral local districts which they have happened to study.*

* It is discouraging to the student of nature to see how much stress is laid by experts on names. Nature hates names. Certainly there was a Portage, a Chemung and a Catskill subdivision of time; but so there is a seventeenth, an eighteenth and nineteenth century: and the distinction is not only mathematical but convenient. But the historian knows very well that the events of the centuries are not confined to the centuries, but run over these artificial mathematical limits without the least regard for them. Actually, practically, they mean nothing. They are mere catchwords. So are most of our geological names; they mean little, if not nothing. Let students of Pennsylvania geology comprehend at the outset of their field work that Portage, Chemung, Catskill are mere catchwords; have no objective value whatever; teach nothing; and will be of little or no help to them in their researches. What they must do is to distinguish the individual beds; name them locally; stick to them as key rocks from county to to county, and let the general formations take care of themselves.

Chemung in Western New York.

The passage of *Portage* upwards into *Chemung* in western New York is described by Prof. Hall (1443, page 248) thus: The top of the *Portage* is usually a heavy thick-bedded sandstone with vertical Fucoids. On it lie shales and shaly sandstones somewhat different from these below, with *Spirifera* and *Atrypa*. On the Genesee river the continuation is so complete that one can see the *Portage* sandstones succeeded upwards by overlying olive shaly sandstone and olive shale; above which lie micaceous, black slaty shale with concretions; above which again lie shales and coarse sandstones with Chemung fossils. On Lake Erie the thick-bedded Portage top sandstone is overlaid by coarse shales holding Chemung fossils; and the contact of the two formations can be traced south to Laona. On Chautauqua Creek the Portage top sandstones are obscure, and there seems to be little change from the *Portage* below to the *Chemung* above.

The passage of *Portage* up into *Chemung* is on the whole most distinctly marked on the Genesee River; namely, by the thick-bedded Portage top sandstones. From the river eastward the difference between Portage and Chemung is quite observable, although the thick-bedded sandstones do not always exist; but the further east we go into middle New York the difference between *Portage* and *Chemung* becomes less and less noticeable. West from the Gennesee river the lower *Chemung* strata, with typical Chemung fossils, are much more like the *Portage* strata than they are in middle New York. In Ohio and Indiana the difference between Portage and Chemung becomes less and less; and the number of Chemung fossils in the Chemung diminishes; so that in the western states no distinction is made between Portage and Chemung. We will find that in Pennsylvania the same thing practically takes place. But the remarkable fact to be noticed is this, that no mention is made in the New York geology of anything corresponding to the *Girard group* of Prof. White in Erie county, Pa.

The Chemung formation in western New York consists of highly fossiliferous shales and thin sandstones in regular courses and infinite variety of texture. Its coarser sandstones have less clay mixed with the sand than those of the underlying Portage formation. The best description perhaps is, that the Chemung formation is a series of thin-bedded sandstones, or flagstones, separated by shales; with numerous layers of impure limestone resulting from a multitude of shells; the whole series weathering brownish-olive. The shales vary in color from deep black to olive and green. The sandstones are often brownish-gray or olive, and sometimes light gray; more generally with a tinge of green or olive. Towards the top of the formation are conglomerates; and in these gravel beds here and there may be found the common fossils of the shales and sandstones.*

The micaceous character of many of the shaly sandstones and shales of the Chemung deserves especial notice. An infinite number of minute flakes of mica are mixed with the rock sand and mud and become visible in the sunshine, giving a glimmer to the outcrop, and even a sparkling look to the soil.† Towards the upper part of the formation, its shales are reddish, coarse, and easily split, with much mica in small glimmering scales; and there is also a slight change in the kinds of shells which lived in these upper micaceous shales. The southern tier of counties in New York, along the Pennsylvania state line, is a belt of high hill country, cut into innumerable valleys; the hills having a

* It will be seen that two persistent and important beds of conglomerate characterize the upper part of the Chemung formation throughout Pennsylvania, and are probably identical with the Oil Sands of Pennsylvania.

† The original source of the mica is unknown; but it is quite certain that it was floated into the sea from distant river mouths draining some continental region of mica schist, such as New England, or the Blue Ridge range of Virginia, or the Philadelphia belt in southeastern Pennsylvania. Consequently we may infer that changes in the relation of sea to land took place during the Chemung age; but at such a distance that no unconformability of strata took place in the New York and Pennsylvania region; that is, the deposits in this part of the sea went on regularly. The floating power of small fragments of mica is well-known; they can be carried by ocean currents many hundred miles from the land.

rounded contour; the valleys being deep and narrow trenches made by the rainfall of innumerable ages, between abrupt sideslopes with frequent low cliffs. On the tops of the highest hills remain patches of the upper conglomerate rocks, evidences of their original extension towards Canada. In the hillsides, the almost horizontal strata are exposed in thousands of places; occasional cliffs affording sections of a few feet or a few yards in height, which, however cannot be combined into a general section of the whole formation together with any great success, as the greater part of every local exposure consists of mud-sand shales which crumble into mere slopes of indistinguishable material sliding down into the valley except where partially kept in place by heavy vegetation. Only by going from valley to valley along the range can the variable character of the Chemung be appreciated.

VIII g. Chemung in middle New York.

The *Chemung formation* (including the *Ithaca Group* at its bottom) is in middle New York not less than 1500′ in thickness.*

On Seneca and Cayuga lakes, or rather in the valleys south of their heads, the *lower Chemung* is well exposed. on the whole darker colored; with more frequent intermixtures of the shales and sandstones; and a less distinct exhibition of well defined and traceable beds.†

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*Estimated from the dip over an outcrop breadth of thirty or forty miles; the height of the hills along the Pennsylvania state line rising to a maximum of 800′ above the valleys. On the Genesee river the top of the Portage is less than 1200′ A. T.; the lowest passes in the Chemung hills to the south ranging from 1500′ to 2000′ A. T.; the highest hills towards the south being scarcely less than 2500′ A. T.

At Lake Erie, the formation is evidently thinner, but could not be measured. In Indiana, *Chemung* and *Portage* together are less than 400′ thick; and still further west they probably thin away to nothing; as they do going south to the Tennessee line.

†The shales themselves are of a dark olive color, like the sands; and it is only high up in the formation (that is toward the state line) that any well defined courses of *black shale* are to be found. This general character suffers little change westward toward the Genesee river. Here however (on the Genesee river) the formation breaks up into better marked sub-divisions. The shales, of a bright green color, often mass themselves into thick beds,

On the Genesee river, the formation may be rudely subdivided in a general way, and without giving thicknesses, thus :—(Hall, page 253).

Chemung sandstones and conglomerates, current bedded.
" *red* sandstones.
" shales and shaly sandstones, gray and olive.
" *green* shales, with layers of gray sandstone.
" *black* slaty shale, with *concretions.*
" olive shaly sandstones.
Portage sandstones.

The *green shale sub-division* in the middle of the formation increases westward from the Genesee river toward Lake Erie ; although the action of the weather in changing the green of the rock to an outside olive color makes the increase of the quantity of green shale in the formation somewhat difficult to observe. The sandstone strata in the same direction become less pronounced.*

Nearer Lake Erie, in Chautauqua county, the shales are still green ; the sandstones mostly thinly laminated, and green also. The important thick masses of dark olive sandstone worked in Steuben and other central counties exist not in the Lake Erie district ; or are poorly represented by thin layers of brownish sandy shale (in Chautauqua county) holding the same fossils. But in proportion as the sandstone element of the *Chemung formation* gradually leaves it (going west) the whole formation becomes thinner ; be-

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scarcely interrupted by any layers of sand. On the other hand, the sand stones, of a lighter color, are less shaly than furher east. Vanuxem says (1842, p. 179) that the *Chemung group* consists of sandstone and shales more or less slaty, and mixtures of the two in all proportions ; the sandstone furnishing good building stone and flags ; the shales often soft and decomposable, but less so than the *Hamilton* shales. The sandstones nowhere show well-defined layers ; and cannot be traced from place to place by any mineral character. A greenish or olive color is general both for the sandstones and shales. Carbonate of iron often replaces the fossils ; particularly the *encrinites*, which are usually about half an inch in diameter, and of different species from those in the *Ithaca* or lower formations. Some of the sandstones are loaded with shells, the cement being limestone ; the rock making a durable building stone, and some varieties of it a good fire stone, one which will not crack or fall to pieces in a hot fire.

*In Cattaraugus county there are thick masses of greenish-gray sandstone, very durable, and readily quarried into large blocks.

cause the increase of green shale is not sufficient to make up for the loss of sandstone. With the thinning of the formation westward there goes on a diminution of fossil species; many eastern species vanishing, and scarcely any new species appearing. And yet, individually regarded, fossils are numerous in many localities; and they are grouped and embedded in the rocks in the same general manner. The micaceous *red* sandy shales also disappear westward, not being noticeable even on the Genesee river.*

So far as the *shells* are concerned, we see a westward diminution of Lamellibranchs—*Avicula*, *Cypricardia*, and allied forms; while the Brachiopods, at first more abundant, finally diminish also.

The fossil *land plants* of the formation afford a still more important indication, inasmuch as they are rather numerous in eastern New York (in the Chemung as well as in the Hamilton); are rare in central New York (only one or two fragments having been found); and are unknown in western New York and Ohio.†

VIII g. Chemung sections.

The general character of the *Chemung strata* can be illustrated by a section or two better than by any description. Prof. Hall selects the two following, every inch of which

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*From all this one may infer that the currents which brought in the *Chemung* stuff flowed from east to west, or from southeast to northwest. But this subject can only be discussed after describing the Pennsylvania outcrops; and whatever conclusion is arrived at respecting the origin of the *Chemung* must be applicable also to the *Portage* and the *Hamilton*.

† Evidently the current which floated them came from the east. It is important to observe, in addition, that many of the thin sandy laminæ of western New York and Ohio are completely covered with minute fragments of *coaly matter* which seems to have been derived from some *land vegetation* brought either from a continent (or islands) in the east; floating quietly on the surface of the sea, then settling to the bottom; and apparently with a certain periodicity like that of the seasons. Similar deposits are going on in lakes and ocean bays now; and it is a common thing to see the water covered with a thick scum of minute particles of wood at a great distance from shore. All this is of the greatest interest to the botanical historian, vaguely hinting at an early appearance of land vegetation on the planet; or at least on those lands which enclosed our Palæozoic gulf or sea.

was measured, all the beds being seen in connection and without repetition.*

Cliff Section at Chemung Narrows.

Shales, olive, fissile, with *Aviculæ*, ...	15′ 0′
Shale, compact, with *Cyathophylla* and other *corals*,	0′ 6″
Shale, compact, with thin courses of sandstone, . . .	13′ 0′
Sandstone, greenish-gray, with seams of shale, . .	10′ 0″
Sandstone, greenish-gray, stained with manganese and iron,	7′ 0′
Shale and sandstone with *Aviculæ*, *Atrypæ*, *etc.*, . . .	5′ 0″
Shale, soft, greenish-olive, ...	3′ 0″
Shale, sandy, compact, with *fossils*,†	2′ 0″
Shale in three distinct courses (2′, 4′ 6′), ...	12′ 0″
Coralline bed, ...	0′ 2′
Shale, olive, with abundance of *fossils*,*	3′ 0″
Sandstone, shaly, compact, ...	2′ 6″
Shale with thin sand layers; abundance of *fossils** . .	6′ 0″
Sandstone with concretions, ...	3′ 0′
Shale with thin sand-layers, ...	8′ 0″
Concealed to river water level, ...	14′ 0″

Section at Painted Post.‡

Sandstone (passing into shale southward), ...	6′ 0″
Shale and sandstone altenartions (with concretions) . .	5′ 0″
Sandstone, ...	1′ 0′
Shales, olive or brownish, fissile, ...	5′ 0″
Sandstone, ...	1′ 0″
Shale, olive or brownish, fissile, ...	6′ 0″
Sandstone, ...	thin
Shale, ...	4′ 0″
Sandstone, grayish-olive (coming and going), . . . 0′ 6″ to	1′ 8″
Shale, ...	4′ 0″
Sandstone, brownish-olive, ...	3′ 0′
Shale, olive and greenish, ...	2′ 0″

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* Many others might be cited showing the same variability in lithological character, and considerable differences in their fossil species. In any exposed cliff the sandy strata can be seen thinning out, and sometimes reappearing; and all such changes in the distribution of the sandy muds and muddy sands represent on a small scale and in a single cliff the infinite variability of the whole formation.

† The fossils are chiefly *Aviculopecten (Avicula) pecteniformis*, *Strophomena membranacca*, *Strophomena interstrialis* (*Strophodonta cayuta*), *Orthis interlineata* (*tioga*), *Spirifera prolata* and *Atrypa aspera*.

‡ The fossils here are species of *Cypricardia*, *Avicula* (*Pleronites spinigera*), *Spirifera*, *Orthis* (large numbers of *Orthis unguiculus*, now *Ambocœlia umbonata*), *Orbicula*, *Loxonema*, *Tentaculites*, etc. The two sections have scarcely a fossil in common; although the deposits are so much alike; except that the shales and sandstones are more deeply colored in the Painted Post section than in that at Chemung Narrows.

Sandstone and shale, interlaminated,	2′ 0″
Shale,	7′ 0″
Sandstone in thin layers,	3′ 0″
Shale,	7′ 6″
Sandstone in thin layers,	5′ 6″
Shale,	3′ 0″
Sandstone in thin layers,	2′ 0″
Shale,	2′ 0″

Kind of stratification.

A contemplation of any of the natural sections afforded by *Chemung exposures* impresses the mind with a conviction that the sands and muds were deposited in comparatively shallow water, and by currents of wide extent and varying rapidity ; moving, as a whole in one direction but with local variations in its course produced by accidents of the bottom, and the shifting of the winds. The run of the tide plays an important role in the drama.*

* The only analogy which we have in the present relation of river deposits to ocean bed must be studied in the larger bays, and off soundings; such as the Bay of Funda ; the belt of sea bottom bordering the Atlantic states ; or the great sub-marine plateau, 100 miles wide down to the hundred fathom line, which surrounds the British Islands and extends into the Bay of Biscay. The phenomena might be studied at the mouth of the Amazon and upon the sea bottom extending in front of it, if it were possible to obtain a view of what is at present occurring there. Sand-banks separated by water-ways are growing in Delaware Bay out of similar materials, sands and muds, under similar conditions, and with a similar structure; the most flagrant feature of which is a false bedding (or oblique lamination) of the strata ; the muddy parts of the deposits settling horizontally into the hollows, while the sandy deposits are carried forward on the inclined planes, and shot down layer upon layer ; the sand-banks growing in length and in width ; the water channels shifting, cutting away what has already been deposited, and transferring the material to some other locality to make some new sand-bank of a different shape. The reader may consult an excellent description of "*Channel fillings in the Upper Devonian shales*," by W. S. Williams, published in the Amer. Jour. Sci. 1881, p. 318, to 320 as studied by him near Ithaca : Wedge shaped beds of sandstone, flat on top, convex below, feathering out both ways between beds of shale. One example is 100′ long, 6′ wide, 9″ thick in the center, top nearly plane, bottom a regular curve, enclosing shales fine, thin, fragile, evenly bedded and wholly argillaceous, with lines of stratification uniform and horizontal ; transition abrupt ; sand bed solid, but faintly laminated on fresh fracture ; lamination colored and wavy near the top ; nearly pure white sand ; course of deposit straight N. 15° E.; north side of channel occasionally abrupt ; under surface like a mud flow, or ripple marked. Such channel ways are numerous around Ithaca but limited to 20′ vertical of rocks, under coarse Chemung sands and shales. All the channels run the same course, and all are from 9″ to 18″ thick and $5\frac{1}{2}$′ to 8′ wide. Shrinkage wrinkles also were noticed.

Oblique lamination characterizes the whole Chemung formation, especially towards the west, where it becomes almost absolutely universal throughout the whole pile of beds; and in this particular the Chemung resembles the Portage formation immediately preceding it in time ; and also the Medina formation along the south shore of Lake Ontario, but not in Pennsylvania. Concretions frequently occur in great numbers in the lower Chemung shales, and show that at that time a considerable percentage of lime water was poured by the rivers into the sea. These concretions are highly calcareous and resemble those which have been already described in previous formations, being seamed with calcite and containing cavities partially filled with *bitumen.* Also in the higher Chemung strata the shaly sandstones often become concretionary, with layers folded around a solid nucleus like an onion. Many lonely concretions lie scattered through the rocks ; but a rock stratum is often filled with imperfect balls ; and in other cases innumerable little waves in the rock indicate its concretionary structure. (See diagram in Hall, 1843, 257). Even when a sandstone stratum is quite massive and solid, not showing the concretionary structure when first quarried, the weather will bring it to light spalling off cup-shaped fragments.*

Ripple marks cover the surfaces of many of the thin-bedded sandstones and compact shales.† (See a good figure of ripple mark in Hall, 1843, 258). A remarkable alternation with horizontally level layers of shale repeated several times in succession is given by Hall on the same page, from an exposure near Lodi, Cattaraugus county.

The *minerals* of the Chemung formation are of no practical importance. Some of the concretion balls hold crys-

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*This is always an evidence of the equal distribution of clay throughout the mass, and also of the very nearly equal size of the particles of sand which are held together by the clay.

† It was once supposed that ripple marks conclusively proved very shallow water ; but it is now known that the action of storm waves extends to a sea bottom under many fathoms of water, re-arranging the sands if they be of the right consistency.

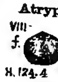
CLXXVI

No. VIII f, Portage Sandstone. Fossils.

Fucoides graphica. Hall, page 241, fig. 104. Vanux

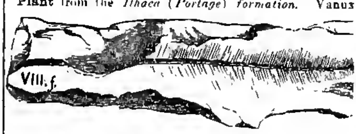
Focoides verticalis. Hall,

Atrypa. tenui linsata

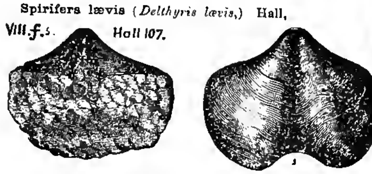


Orthis tenui striata

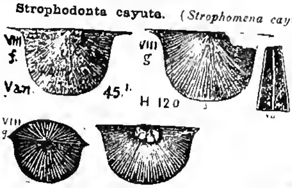
Plant from the *Ithaca* (*Portage*) *formation.* Vanux



Spirifera lævis (*Delthyris lævis*,) Hall,



Strophodonta cayuta. (*Strophomena cayuta ; Strophomena interstrialis ; Orthis interstrialis ; Leptæna interstria*.



Strophomena ithacensis.

Goniatites bicostatus.

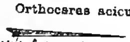
Cyathocrinus ornatissimus Hall

Bellerophon striatus

VIII
f
H 107

Goniatites complanatus

Orthoceras aciculum, Hall.



tals of *Galena*, *Calcite* and *Pyrites.* Iron pyrites often takes the place of fossil shells. The stems of Crinoids and other fossils have been changed into calcite; very frequently in the upper strata; rarely in the lower. The sulphate of iron and alumina are so common at the surface that iron pyrites must be universally diffused throughout the formation; and the appearance of the black oxide of manganese (wad) is so common, especially in rapids and below cascades, that this metal also must be diffused through the whole body of clay in the formation.

The *soil* of the Chemung belt is everywhere a compact clay loam charged with an abundance of small angular pieces of stone (flat gravel); mixed in the valleys with northern drift.

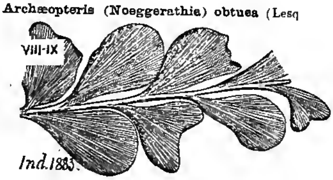
VIII g, Chemung fossils in New York.

Fossil shells are incredibly numerous in the Chemung formation, and the variety of genera and species is very great. But a change in the animal sea life had been taking place during Portage and Genesee ages. In the water-region under consideration animal life had almost disappeared. It is therefore necessary to suppose that shells which had previously lived in great abundance in Hamilton times migrated to a distance, and returned again at the beginning of the Chemung age. For the interval of geological time represented by the Genesee and Portage formations we have no scale; but enough time must be imagined for the production of all these changes in genera and species which we see took place previous to their return. The world of Lamellibranchs and the world of Brachiopods contained in the *Hamilton* formation crowd again the Chemung; but very few specific *Hamilton* forms can be found in the *Chemung.* The number of Brachiopod species is about as great in one formation as in the other. The genus *Avicula* is much more abundant, both in species and individuals, in the *Chemung* than in the *Hamilton.* Species and individuals of *Nucula*, of *Cypricardia*, and some other genera, are about equally numerous in *Hamilton* and in *Chemung.* But *Chemung trilobites* are rare; and there are few species of Hamilton corallines.

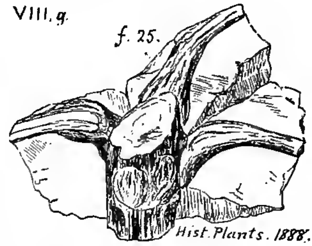
CLXXVIII

No. VIII g, Chemung fossils continued.

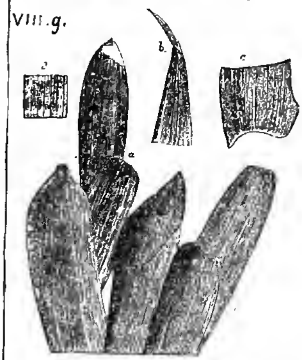
Archæopteris (Noeggerathia) obtusa (Lesq



Caulopteris lockwoodi. Dawson.

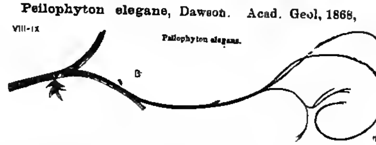


Cordaites robbii. Dawson. Geological Hist

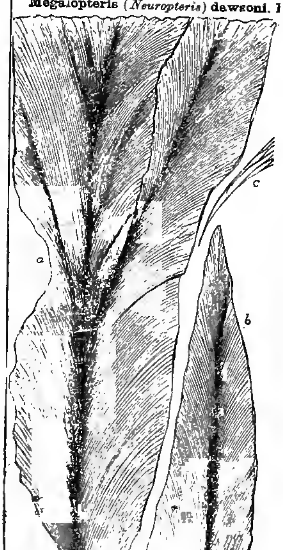


Cyclopteris jacksoni, Dawson

Psilophyton elegans, Dawson. Acad. Geol, 1868,



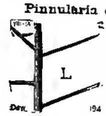
Megalopteris (*Neuropteris*) **dawsoni.** I



Psilophyton elegans. Dawson. Geological history of plants, 1888, page 66, fig. 21. —*Erian* (Devonian) rocks.

Lycopodites matthewi,

Pinnularia dispalans,



Psilophyton princeps, Dawson. Geol. Canada, 1863,

Fossils are very unequally distributed among the subdivisions of the *Chemung*. Moreover, the animals themselves were distributed very unequally over the sea bed during the deposition of this and that subdivision; living apparently in banks or colonies, so that in some places few or no specimens can be collected from the rock, whereas at other places the rock is completely filled with them; while certain localities are distinguished from the country at large by a great abundance of certain forms which are hardly to be found anywhere else.*

Scarcely a locality abounding in fossils can be examined but some new form will be discovered among them; and in this respect the Chemung contrasts strongly with the Hamilton formation; for where the Hamilton is well developed all the known Hamilton forms would be likely to exist in any given single column of section; at least such is the case in western New York.

Land-plant fragments have been found (as already mentioned) in the Hamilton and Genesee formations of eastern New York. They have been found also in the lower Chemung. During all these ages the land vegetation was gradually developing the forms which became afterwards so abundant in the Coal measures. Near the top of the Chemung formation in New York plants very much like those of the Coal measures were drifted into the sea. Judging from the perfect preservation of some few of the specimens the land could not have been far away from where they are found in the rocks; but most of them are mere fragments and may have floated far. A very perfect fern (*Sphenopteris laxus*) from Sexton's quarry, Pine valley, Chemung county, is figured by Hall (1843, 275). A curved fragment or

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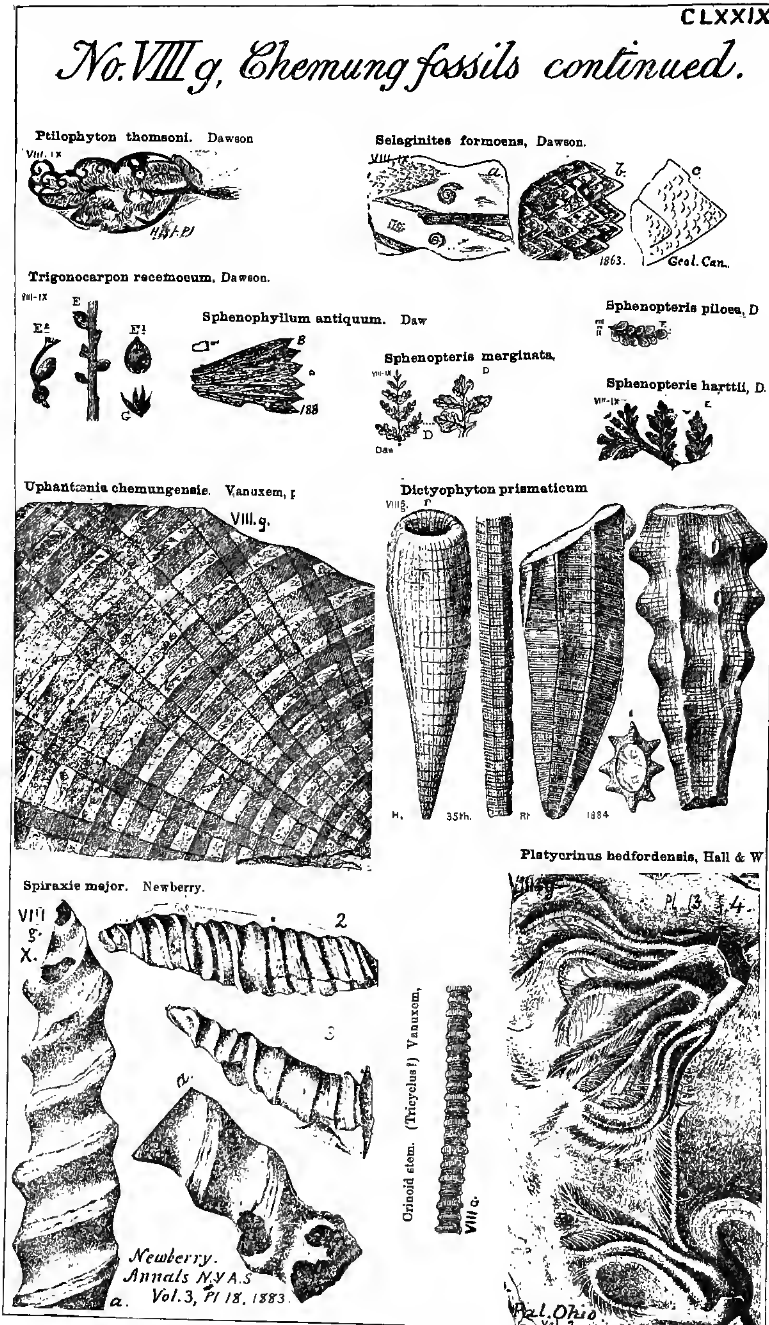
*For instance, the green sand-shales of Rockville and Phillipsburg contain a great abundance of *Avicula*, *Lima* (now *Aviculopecten*, *Pernopecten*, *Limoptera*), *Cypricardia*, and *Inoceramus* (now *Mytilarca*); while on the contrary, *Spirifera* and *Atrypa* are much less common. Again the dark sandstones and sandy shales of Painted Post, Jasper, Troupsburg, and Dexterville contain myriads of the little *Orthis unguiculus* (*Ambocœlia umbonata*) and large numbers of *Spirifera* and *Atrypa*; but more rarely *Avicula*. Again at Chemung Narrows can be got several species of *Avicula*, with large numbers of *Atrypa* and *Strophomena*; but here very few of the fossils named above can be found.


CLXXIX
No. VIII g, Chemung fossils continued.
Ptilophyton thomsoni. Dawson
Selaginites formoens, Dawson.
1863.
Geol. Can.
Trigonocarpon recemocum. Dawson.
Sphenophylum antiquum. Daw
Sphenopteris merginata,
Sphenopteris pilosa, D
Sphenopteris harttii, D.
Uphantænia chemungensis. Vanuxem,
VIII. g.
Dictyophyton prismaticum
35th.
1884
Platycrinus bedfordensis, Hall & W
Pl. 13 f. 4.
Pal. Ohio
Vol. 2.
Spiraxis major. Newberry.
VIII g. X.
Newberry.
Annals N.Y.A.S
Vol. 3, Pl 18, 1883
Crinoid stem. (Tricyclus?) Vanuxem,
VIII G.

branch of a tree-fern (*Sigillaria chemungensis*) 18″ long and 2″ thick, found at Wisner's quarry near Elmira, is figured on the same page. Other similar fragments have been found elsewhere. Reeds (*Calamites*) have also been found.

Very few species of *Polyps* have been found in western New York; but some species lived in great numbers. The *Alveolites* (*Millepora*) *gracilis* is found from the little lakes to Lake Erie. A bryozoon (species of *Retepora*) is equally abundant. Other species occur rarely. *Corals* are not common; but near Bath, and at Chemung, a species of *Cyathophyllum* occurs not seen elsewhere; and at one or two places Prof. Hall saw specimens of *Turbinolopsis*. A curious fern like fossil, but probably not a plant, is found in considerable numbers at Ithaca, Hector and Enfield (Hall, 1844, p. 273). It grew in tufts from a root; was of uniform size and feathered like a pen (see figure in Hall, 1843, 273).

Sea urchins lived in the Chemung seas. *Eocidaris drydenensis* (Vanuxem) from the Chemung group is mentioned in Miller's Amer. Pal. Fossils, p. 78. But a reference to the report of the 3rd district of New York, 1842, seems incorrect.*

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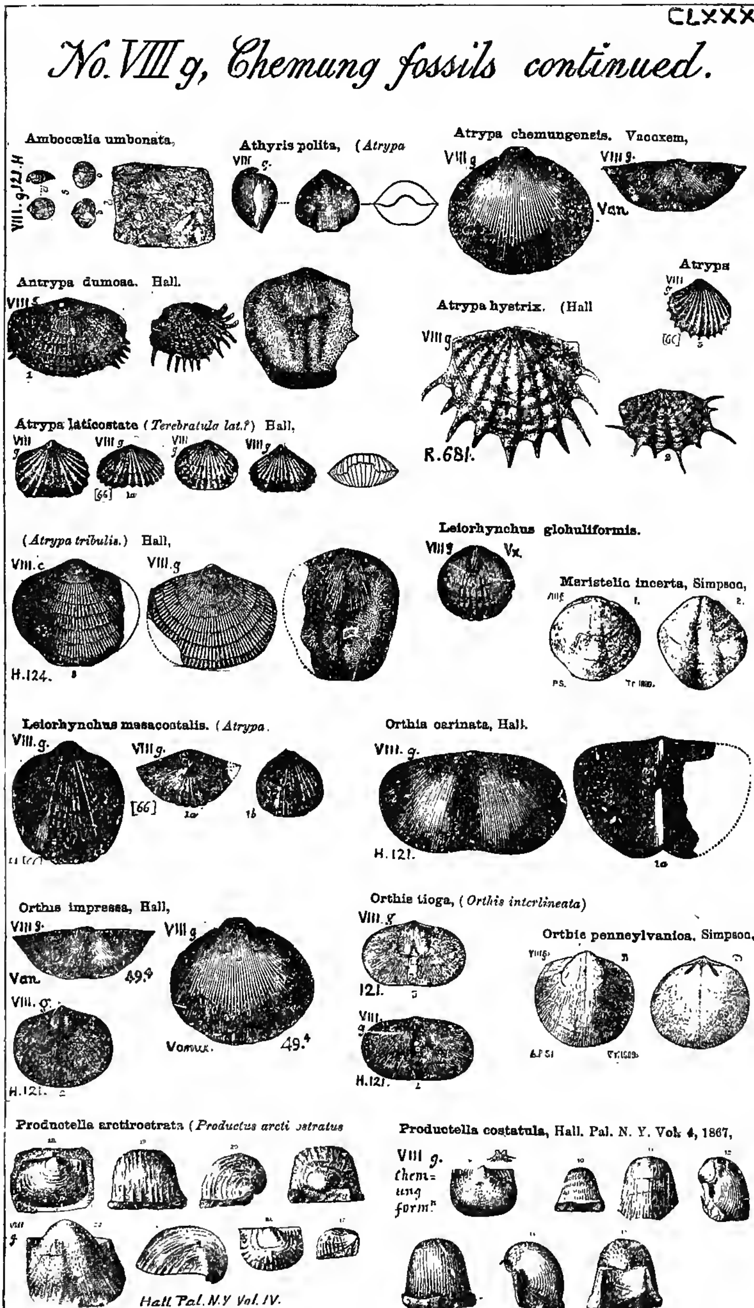
* Thirty or forty years ago it was not supposed possible to find any Cidarids (from Kidaris, a turban) in rocks older than the Trias. In 1856 however Ed. Desor published in his great work on the Echinoderms 20 palæozoic species, all Cidarids. (Note sur la classification, etc. Bull. Soc. N. Neufchâtel, vol. 4). *Eocidaris scrobiculata* and *lævispina* from the European Devonians were drawn by Sandberger (see Desor's copied figs. plate 21). *Archæocidaris urii*, Desor, in the Irish Carboniferous limestone shows spines curiously set with smaller spines in spiral like the leaves of a plant. This is the only clew that I have to the nature of a remarkable form which I detected in a slice of limestone obtained from Mr. Boyd, superintendant of the Cornwall magnetic iron ore mines in Lebanon county, and supposed at first to have been taken (like the other specimens of a suit subjected to the wheel for microscopic examination) from the ore bank. Every effort to obtain the real locality of the rock failed, and if the form be an echinoderm spine its age remains unknown.—That Echinids lived long before the Devonian age is shown by the *Palæochinus phillipsiæ* found in Silurian rocks in England (Geol. Sur. G. Britain, II, p. 384, plate 29, Gickie's Text Book, chapter on May Hill sandstone, our Medina No. IV, page 674).—See the star fishes on plate LIV, p. 610 above; and plate XXXX, p. 530 above. See also the notice of Walcott's sea urchins in Cambrian rocks, on page 194 above.


CLXXX
No. VIII g, Chemung fossils continued.
Ambocœlia umbonata,
Athyris polita, (Atrypa
Atrypa chemungensis. Vanuxem,
Atrypa
Antrypa dumosa. Hall.
Atrypa hystrix. (Hall
R.681.
Atrypa laticostata (Terebratula lat.?) Hall,
(Atrypa tribulis.) Hall,
H.124.
Leiorhynchus globuliformis.
Meristella incerta, Simpson,
Leiorhynchus mesacostalis. (Atrypa.
Orthis carinata, Hall.
H.121.
Orthis impressa, Hall,
Orthis tioga, (Orthis interlineata)
Orthis pennsylvanica. Simpson,
Productella arctirostrata (Productus arcti ostratus
Productella costatula, Hall. Pal. N. Y. Vol. 4, 1867,
VIII g. chemung form.
Hall Pal. N.Y Vol. IV.

Among the *brachiopod* shells in the Chemung of western New York Prof. Hall selected the following "as most characteristic" of the formation, although other species were "perhaps equally numerous":—*Strophodonta perplana*, var. *nervosa* (*Strophomena nervosa*) remarkable for the extension of its hinge-line for full half an inch beyond the corners of the semi-circular valve as two straight spines. Surface marked by wavy nerve-like striæ, becoming more numerous as they radiate towards its edge; and between are finer striæ. The shell looks like the nerved wing of some insect; and this and its long spines, distinguish it.—*Strophodonta cayuta* (*Strophomena interstrialis* *); one of the most widely distributed species; with a somewhat different aspect in the shales, sandstones and limy layers.

Streptorhynchus (*Strophomena*) *pectinaceus*, with 24 to 28 prominent sharp striæ; and between each pair two or three less prominent; resembling *Strophodonta Cayuta* except that the rays are fewer and more prominent. Widely distributed.—*Streptorhynchus* (*Strophomena*) *bifurcata* with 34 to 36 ribs at the hinge, forking regularly once or twice; widely distributed east and west for 150 miles.—*Streptorhynchus* (*Strophomena*) *arctostriata*, with striæ numerous, crowded and unequal.—*Orthis carinata* with a lower valve very convex, and upper valve flat, with a sharp ridge (keel, *carina*) along its center, showing strongly on the *cast* of *its inside surface*, which has a heart-shaped impression with a sharp point at the beak, and flat below. The casts of this shell are numerous and sufficient to tell the species;—*Orthis impressa* with a short hinge, nearly flat upper valve; surface covered with fine and equal radiating scratches; and *cast* of muscular impression at beak small and double; in the soft green shales of Elmira and elsewhere.—*Orthis tioga* (*interlineata* of England, Sowerby and Phillips). Hinge short for the great width of the shell, which is depressed. Upper valve flat, with a ridge along the center. Lower valve moderately convex, with a shallow depression from beak to base, and its surface scratched in numerous,

* *S. inequistriata* and *S. mucronata* (Jour. A. N. S. Vols. 8); also *Orthis* and *Leptæna interstrialis* of Phillips.


CLXXXI
No. VIII g, Chemung fossils continued
Productella boydii. Productus boydii, Hall.
Hall. Pal. N.Y. Vol. IV.
Productella exanthemeta (Productus exanthemat
Hall Pal N Y Vol 4.
Productolla hirsuta,
VIII c.
674
Productella hystricula, Hall.
6, restored.
Hall. Pal. N.Y. Vol. IV. 1867. pl. XXVI.
Productella lachrymosa (Strophomena lachrymosa. Con
Hall Pal N.Y. Vol IV
Productella lachrymosa, var. lima. Hall,
Productella striatula, Hall. Pal. N. Y. Vol. 4, 1867,
VIII.g.
Hall. Pal.N.Y. Vol. IV. P. 177. Pl. XXV.
Productella onusta. Hall. Pal. N. Y., Vol. 4, 1867.
Productella rarispina, (Productus rarispinus. H.
VIII.g.
Hall. Pal. N.Y. Vol. IV. Plate XXIV.
Productella speciosa, (Productus speciosus, Hall.
Hall. Pal. N.Y. Vol. IV. Pl. XXV.
Productella spinulicosta. (Productus.
Hall. Pal. N.Y. Vol. IV.
Rhynchonella medialis, Simpson.
Spirifera acuminata, (Del
VIII.g.
H.123.

unequal, or forking rays. *—*Ambocœlia umbonata* var. *gregaria* (*Orthis unguiculus*, *Atrypa unguiculus* of Sowerby, *Spirifera unguiculus* of Phillips). A hemispherical little shell, with a very convex lower valve, with a remarkable central groove, and a flat or slightly convex upper valve, and a large, inflated, incurved beak. There is great variety in its proportion of width to length. *Casts* of it are abundant covering surfaces many feet in extent, with a colony of old and young together ; as shown at the top of plate CLXXX. It greatly resembles the *Ambocœlia umbonata* of the Hamilton rocks.

The *Spirifer* (*Delthyris*) genus of shells is even more abundant than the genus *Strophodonta* (*Strophomena* and *Orthis*) last described, and than the genus *Atrypa* next to be described, in the Chemung formation. All three, subdivided into many so called species, crowd by millions the greenish and olive shales and shaly sandstones of the formation up to its top ; but stop there in New York, ceasing to live as soon as the Catskill red sandstone and shale deposits began to be laid down upon the sea-bottom. The change in eastern New York is abrupt, and the division plane between the two formations easy to fix. But in Pennsylvania we shall find a different state of things ; alternations of Chemung and Catskill strata occupying at least a thousand feet of the columnar section ; and plenty of Chemung fossils, especially *Spirifers*, far up in what ought to be the Catskill part of the series. This happens where the Catskill formation is several thousand feet thick. But it thins away rapidly into western Pennsylvania and western New York, in the country back of the Allegheny mountain ; disappearing entirely in the oil regions, where the Chemung fossils continue to be abundant in the strata to within a few hundred feet of the base of the great Conglomerate of the coal measures.†

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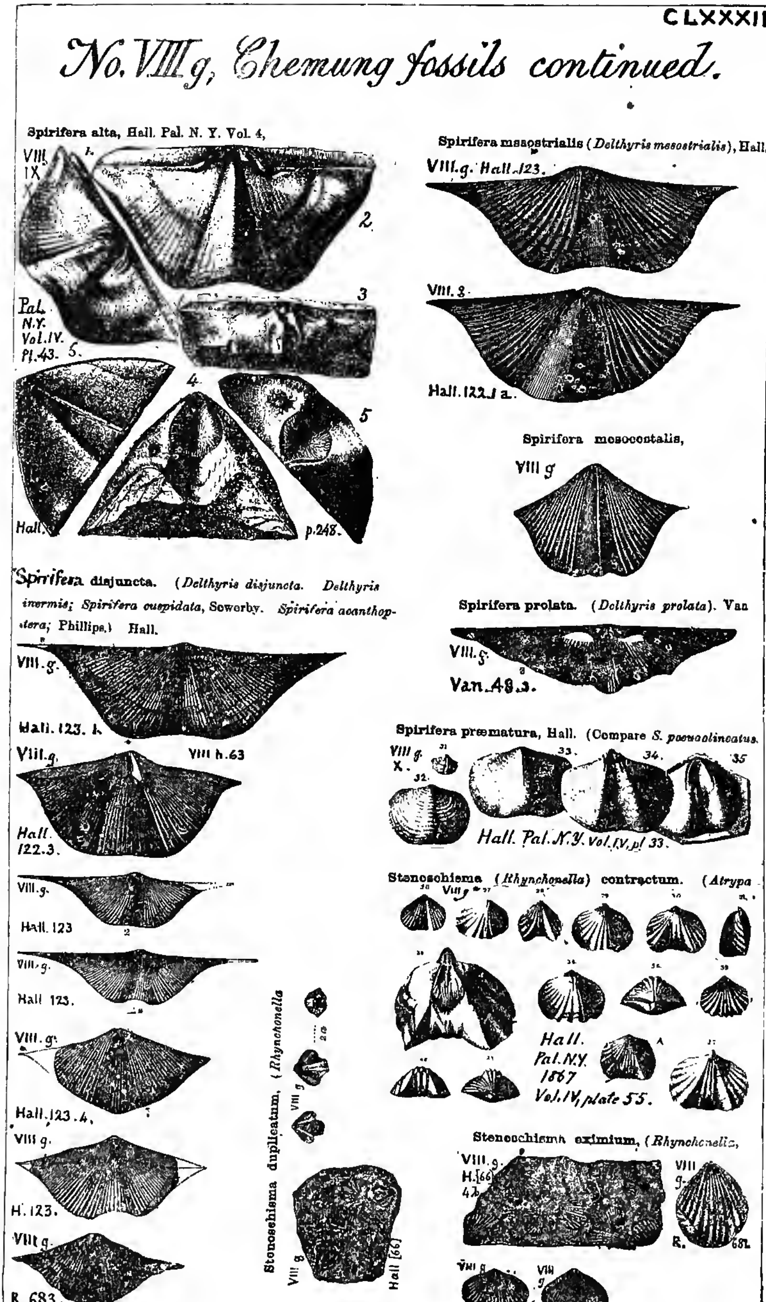
* Sowerby's figures prove the identity of the shell in England and America. Fig. 3 on plate CLXXX is a cast of the outside surface of upper valve, showing the ridge as a hollow. Fig. 4, lower valve showing near the beak the spaces from which the subrostral plates have been removed.

† As the pigmy five-toed horselet of the early Cretaceous and Tertiary ages seems to have assumed more and more, through successive generations, the


CLXXXII
No. VIII g, Chemung fossils continued.
Spirifera alta, Hall. Pal. N. Y. Vol. 4,
VIII IX
2
3
Pal. N.Y. Vol. IV. Pl. 43.
4
5
Hall.
p. 248.
Spirifera mesostrialis (Delthyris mesostrialis), Hall.
VIII. g. Hall. 123.
VIII. g.
Hall. 122. a.
Spirifera mesocostalis,
VIII g
Spirifera disjuncta. (Delthyris disjuncta. Delthyris inermis; Spirifera cuspidata, Sowerby. Spirifera acanthoptera; Phillips.) Hall.
VIII. g.
Hall. 123.
VIII. g.
VIII h. 63
Hall. 122. 3.
VIII. g.
Hall. 123
VIII. g.
Hall 123.
VIII. g.
Hall. 123. 4.
VIII g.
H. 123.
VIII g.
R. 683.
Spirifera prolata. (Delthyris prolata). Van
VIII. g.
Van. 48. 3.
Spirifera præmatura, Hall. (Compare S. pseudolineatus.
VIII g.
X.
33.
34.
35
32.
Hall. Pal. N.Y. Vol. IV. pl 33.
Stenochisma (Rhynchonella) contractum. (Atrypa
Hall. Pal. N.Y. 1867 Vol. IV, plate 55.
Stenochisma duplicatum, (Rhynchonella
VIII g
VIII g
Hall [66]
Stenochisma eximium, (Rhynchonella,
VIII. g.
H. [66]
VIII g.
R.
681.
VIII g
VIII g

Many other so-called species of *Chemung Spirifers* have been described; such as *Spirifera acanthoptera, alta, amara, cooperensis, cyrtiniformis, gaspensis, huronensis, insolita, lævis, missouriensis, norwoodi, orestes, osagensis, peculiaris, pharovicina, præmatura, prolata, superba, texta, vernonensis, whitneyi.**

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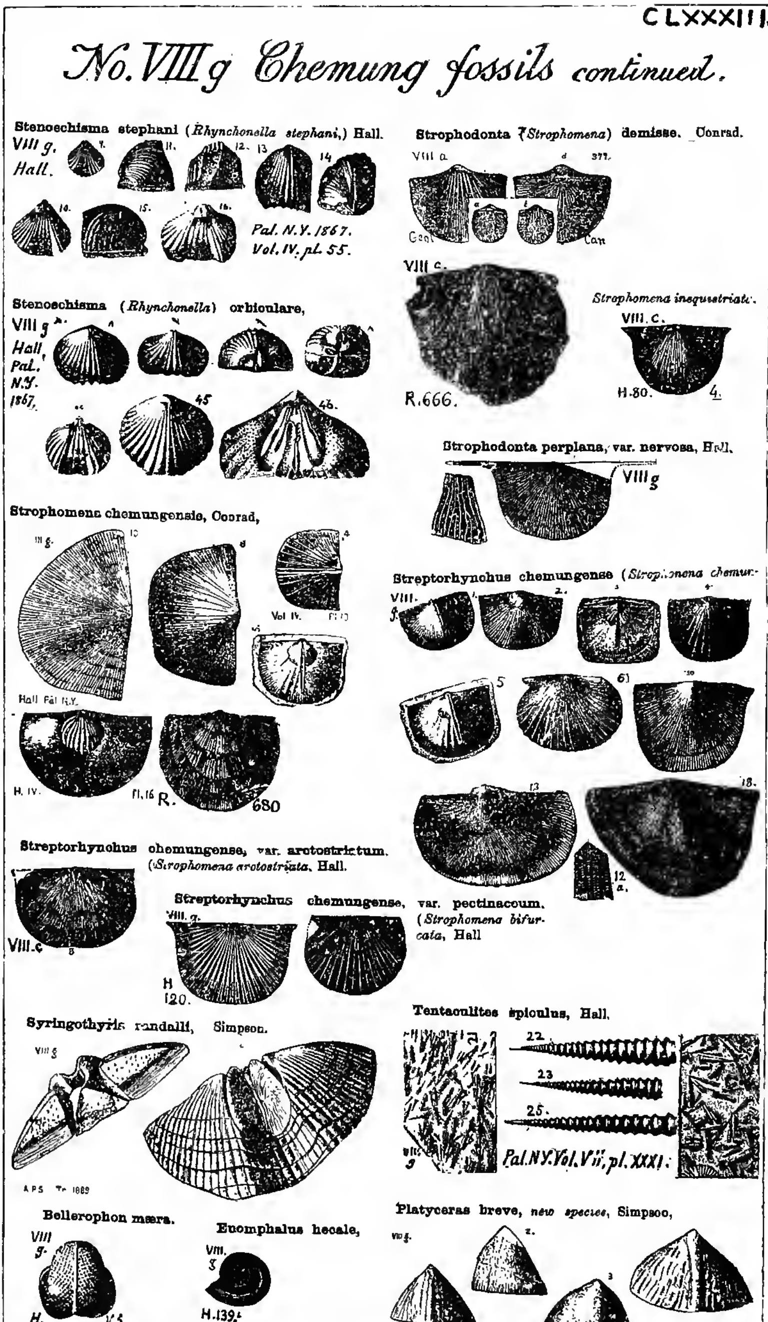
hoofed form and giant size of the modern horse, so the *Spirifer* shell of the Silurian (*Niagara*) age, seems to have altered its shape and markings through the Oriskany and Hamilton ages, until it became the well known *Spirifera mesostrialis, mesocostalis,* and *disjuncta* of the Chemung age. How many thousands or scores of thousands of years elapsed while the changes from form to form were going on is quite unimportant; nor how many varieties of form appeared in succession or in branching parallel lines. The Spirifer was always a Spirifer in its essential structure as a peculiar shellfish different from other brachiopods not merely in the shape and marking of its shelly covering but in the arrangement of its internal organs. Not to speak of the heaven-wide difference between the front and back idea of a brachiopod, and the right and left sided idea of a lamellibranch,—a difference which no Darwinism can even plausibly suggest a method of bridging over, by family development through successive generations, we have here an evident difference of two intelligent creative ideas. The error of evolutionists is that they argue as if it had been proved that the force of evolution or variation (whatever that mysterious force may be) is without limits. They might as well argue from the acknowledged law of the convertibility of forces that as motion may turn into heat and heat into electricity, electricity may turn into matter, or spirit, or any other phenomenon of the universe. Perhaps it does; but a perhaps is not science. Any fool may suggest any kind of explanation for anything he sees; but what are his suggestions worth?

* Named by Winchell, Hall, and Meek. See S. A. Miller's list in N. A. Geol. and Pal. The question is are these true species, or only varieties, *Spirifera calcarata, gigantea, grandæva, lonsdalli, protensa, verneuilli,* are now generally recognized as meaning merely *Spirifera disjuncta.* Some of the retained specific names are founded on the mere length and sharpness of the projecting pointed ends of the hinge line; others on the abnormal largeness or smallness of the animal; others on some slight difference in marking. When zoologists call the terrier, spaniel, greyhound and St. Barnard breeds mere varieties of the species Dog we may well doubt the value of the specific differences of the Spirifers of the Chemung formation. In point of fact any large collection of *Chemung spirifers* suggests mere variety as strongly as a pigeon cote well stocked with the different strains of fancy birds. It is hard to imagine that, as pumpkins and squashes, growing in the same field, produce such notable differences in the fruit of both kinds, the widest apart species of *Spirifers*, living on the same sea bottom, should not effect by an admixture of their spawn all the varieties on which so many specific names have been bestowed. These names are convenient as references to figured descriptions of specimens in cabinets; but their value may not exceed this practical convenience. Certainly it is hazardous to use these names as arguments for the relative age of any one form;


CLXXXIII.
No. VIII g Chemung fossils continued.
Stenoechisma stephani (Rhynchonella stephani,) Hall.
VIII g. Hall.
Pal. N.Y. 1867. Vol. IV. pl. 55.
Strophodonta (Strophomena) demissa. Conrad.
VIII c.
R.666.
Strophomena inequistriata.
VIII. c.
H.80.
Stenoechisma (Rhynchonella) orbiculare,
VIII g Hall, Pal. N.Y. 1867.
Strophodonta perplana, var. nervosa, Hall.
VIII g
Strophomena chemungensis, Conrad,
Vol IV.
Hall Pal N.Y.
H. IV.
R. 680
Streptorhynchus chemungense (Strophomena chemun-
VIII. g.
Streptorhynchus chemungense, var. arctostrictum. (Strophomena arctostriata. Hall.
VIII.c
Streptorhynchus chemungense, var. pectinaceum. (Strophomena bifurcata, Hall
VIII. g.
H 120.
Syringothyris randalli, Simpson.
VIII g
Tentaculites spiculus, Hall.
Pal. NY. Vol. V ii, pl. XXXI.
Bellerophon maera.
VIII g.
H. V.5
Euomphalus hecale,
VIII. g
H.139.
Platyceras breve, new species, Simpson,

Three spirifers: *disjuncta*, *mesostrialis*, and *mesocostalis* discussed in the foot note, are figured (after Hall) on a reduced scale (one half-nature) on plate CLXXXII above. All three have their hinge line projected and pointed; all are ribbed; all have a deep groove or middle fold. But the *disjuncta* has 25 to 30 small plain ribs each side of the fold,

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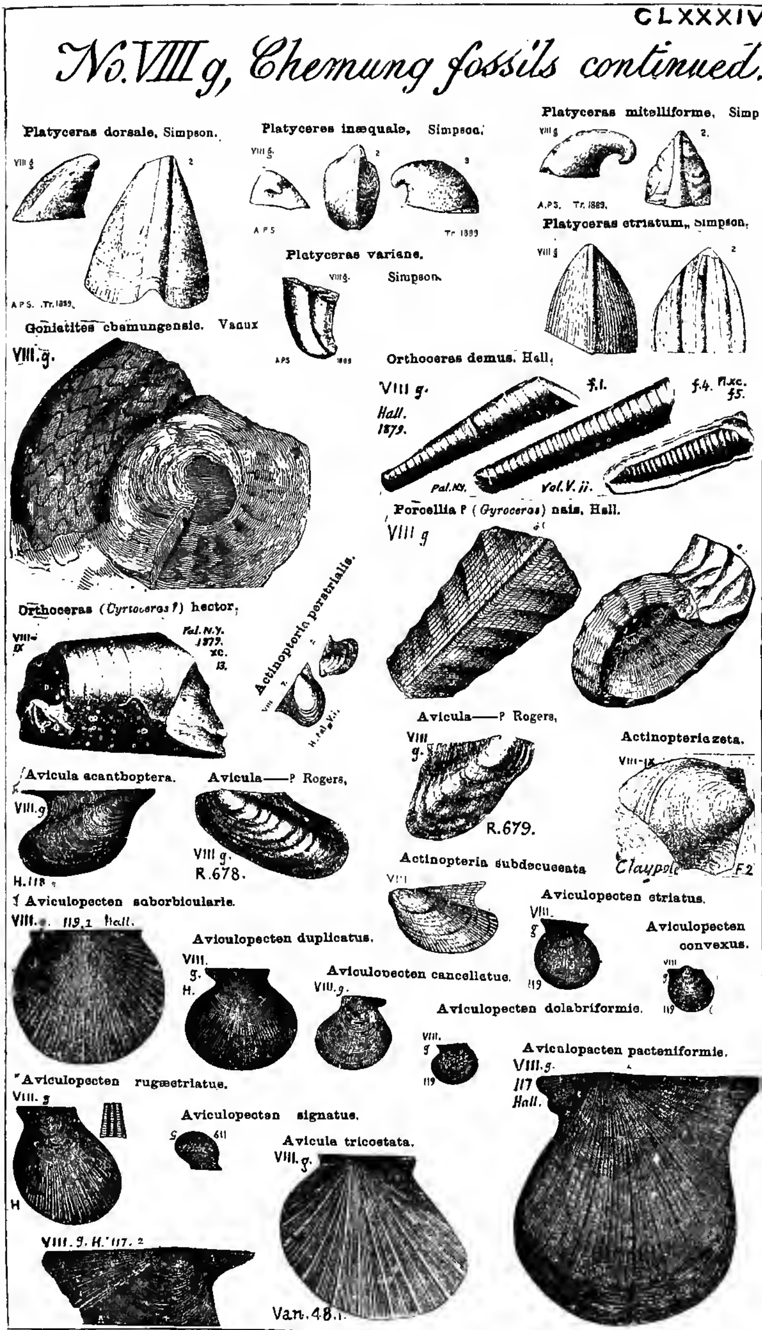
or to use the varieties of form as a key to the order of stratification; except perhaps at this or that special geographical point on the map.

In the survey of the outcrops in New York a fixed order of time was noticed in the appearance of three remarkable Spirifers mentioned; the *mesostrialis* first; then the *mesocostalis:* lastly the *disjuncta*. At no place were their remains found in the same stratum; but on the contrary the *disjuncta* always highest in the series; the *mesocostalis* lower; the *mesostrialis* lowest.

The excellence of the observers has always been acknowledged; the accuracy of their observations where the rocks were exposed cannot be impugned; the possibility and even probability of such a natural history arrangement of three species of shells in any small limited area, or in many places over a larger area, must be allowed; but it is evident that the establishment of such a generalization in the study of a belt of country like that which carries the Chemung outcrop from the Hudson to Lake Erie, across a multitude of valleys separated by highlands, wooded and drift covered, would have a powerful and perhaps a confusing and misleading effect on the observers' identifications of strata from valley to valley. There would be an irresistible tendency to put all isolated exposures holding *mesostrialis* lower, and those holding *disjuncta* higher, than those holding *mesocostalis;* a process of self-deception not only natural and innocent, but easy, on account of the peculiarly gentle dip southward, and the total absence of those topographical guides which steeply dipping hard strata afford in the shape of well defined ridges, making fixed and visible horizons of sub and superposition, to which the vertical range of all fossils can be referred.

The development of *mesostrialis* into *mesocostalis*, and of that into *disjuncta* is after all a mere supposition, an empirical theory from a few observations in the New York outcrop. It would not be a proved law by finding three distinct rock-horizons of the three species, arranged in that order, at one, or even at several good and long exposures; for, the theory of exile and return, or of simple immigration of the three species in that order, would have equal value. Basques, Celts, Romans and Franks settled in France in that order; but they were not developed from one another. Moreover, it would not be likely that the same development would take place over the whole Chemung sea-area; with an undisturbed regularity. wholly out of harmony with all other features of the formation; which are (on a grand scale) as irregular as the greatest lover of variety in nature could desire.

In Pennsylvania no such law of Spirifer development and distribution has been made out; on the contrary the three species mentionrd are mixed together in rocks at the same age. They not only lived but continued to live to the end of the Chemung age, and far into the following Catskill age; as will be shown hereafter.



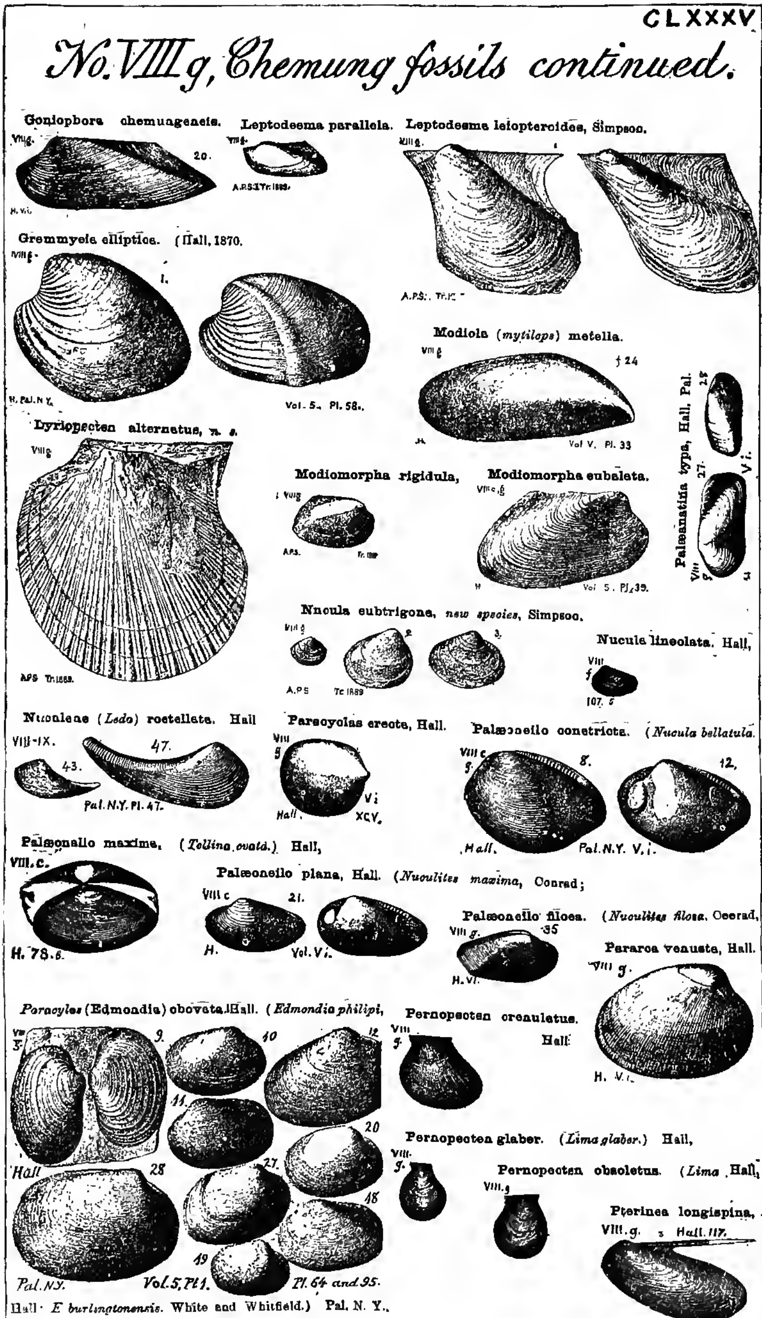
CLXXXIV
No. VIII g, Chemung fossils continued.
Platyceras dorsale, Simpson.
Platyceres inæquale, Simpson.
Platyceras mitelliforme, Simp
Platyceras striatum, Simpson.
Platyceras varians, Simpson.
Goniatites chemungensis. Vanux
Orthoceras demus. Hall.
Porcellia ? (Gyroceras) nais, Hall.
Orthoceras (Cyrtoceras ?) hector.
Actinopteria perstrialis.
Avicula —— ? Rogers.
Actinopteria zeta.
Avicula acanthoptera.
Avicula —— ? Rogers.
R.679.
R.678.
Actinopteria subdecussata
Claypole
Aviculopecten suborbicularis.
Aviculopecten striatus.
Aviculopecten convexus.
Aviculopecten duplicatus.
Aviculopecten cancellatus.
Aviculopecten dolabriformis.
Aviculopecten pecteniformis.
Aviculopecten rugæstriatus.
Aviculopecten signatus.
Avicula tricostata.
Van. 48.

and the rays in the fold smaller and forking to say 15 at the margin of the shell. The *mesocostalis* has a very high back, a very convex lower valve, and a deep fold *doubled* by a single central rib. The *mesostrialis* has a broad deep spreading fold full of striæ or minute ribs, and its side ribs are finely striated lengthwise and sometimes crossed by raised plates of growth. (Two other species have a striated fold, but one has flat ribs and the other sharp angular ribs.) At Chemung, N. Y. the *disjuncta* lived in a crowd of *Atrypa laticostata*. At Angelica N. Y. the *mesocostalis* is found in grey sandstone.

The other *Spirifers* figured by Hall in his 1843 report are: *Spirifera cuspidata*, with long sharp ears (a variety of *S. disjuncta*), occurring locally in immense numbers. *Spirifera* (*acanthota*) *acanthoptera*, with a hinge line running out both ways in a long sharp spine; so much like the *S. cuspidata*, that it also may be considered *S. disjuncta*, or a young variety.—*Spirifera inermis*, now recognized as *disjuncta*, with 8 forked ribs in the fold; in Chautauqua county layers of it several inches thick and yards long. —*Spirifera mucronata*, differing from that of the *Hamilton* formation only in having its well defined *middle fold divided* by a small central rib near the bottom. About 14 rounded *ribs* on each side of the fold, which are *imbricated*, or crossed by wavy plate-edges like scales, half way from the margin of the shell towards the beak. *Spirifera acuminata*, with a deep fold crossed by wavy plate edges, usually bent.

Vanuxem in his report of 1842, figures a *Spirifera* (*Delthyris*) *prolata*, as a very common *Chemuny* shale, which might be at first sight taken for the *Hamilton Strophodonta* (*Strophomena*) *mucronata* but that its middle groove is covered with fine ridges; and also in perfect specimens, the whole surface of the shell. Its very expanded wings are also bent into deep waves towards their ends. The figure (after Vanuxem) on pl. CLXXXII shows the inside and the hinge.—Another *Spirifera* (unnamed by him) he figured as very abundant.

The Atrypa family of shells, having no hole in the beak,


CLXXXV
No. VIII g, Chemung fossils continued.
Goniophora chemungensis.
Leptodesma parallela.
Leptodesma leiopteroides, Simpson.
Grammysia elliptica. (Hall, 1870.
Vol. 5. Pl. 58.
Modiola (mytilops) metella.
Vol V. Pl. 33
Palæanatina typa, Hall, Pal.
Lyriopecten alternatus, n. s.
Modiomorpha rigidula,
Modiomorpha subalata.
Vol 5. Pl. 39.
Nucula subtrigona, new species, Simpson.
Nucula lineolata. Hall,
Nuculana (Leda) rostellata. Hall
Pal. N.Y. Pl. 47.
Paracyclas erecta, Hall.
Palæoneilo constricta. (Nucula bellatula.
Pal. N.Y. V. i.
Palæoneilo maxima, (Tellina ovata.) Hall,
Palæoneilo plana, Hall. (Nuculites maxima, Conrad;
Palæoneilo filosa. (Nuculites filosa, Conrad,
Pararca venusta, Hall.
Paracyles (Edmondia) obovata. Hall. (Edmondia philipi,
Pernopecten crenulatus. Hall.
Pernopecten glaber. (Lima glaber.) Hall,
Pernopecten obsoletus. (Lima Hall,
Pterinea longispina,
Hall. 117.
Pal. N.Y.
Vol. 5, Pl. 1.
Pl. 64 and 95.
Hall · E burlingtonensis. White and Whitfield.) Pal. N. Y.,

were also prolific. Some were covered with spines, like the "bushy" *Atrypa dumosa* (represented reduced, after Hall, CLXXX above), which however when extracted from the rock leaves its spines behind and looks like the English *Atrypa squamosa.*—*Atrypa hystrix* had only 8 broad ribs projecting in long spines from the edge of the shell; a strikingly distinct species in the outcrops south of Bath, Steuben Co., N. Y.—*Atrypa reticularis* (*tribulis*) with a beautiful surface and a flat lower valve.*—*Atrypa tenuilineata*, a little shell, with its surface covered with fine radiating lines; and a small beak.—*Productella hirsuta*, var. *rectispina* (Vanuxem's *Strophomena membranacea*)† is exceedingly abundant in middle New York; covered with little spines which are left in the rock; closely resembling a spiny *Hamilton* shell.‡

Lamellibranchs, the winged cockle shells (*Aviculoids*) are very numerous, and some of the species very abundant at certain horizons, especially in the olive green sandy shale division on the Genesee river. The large *Aviculopecten* (*Avicula*) *pecteniformis*, 3″ by 2″, seems to characterize the horizon at the Chemung Narrows. Its *upper valve* is flat; either smooth, or scratched with fine concentric lines; strong radiating ribs on its hind wing, and a fold on its sharp front wing; the *lower valve* slightly rounded, and (with its large hind wing) marked with strong ribs of unequal size; its small front wing showing one strong fold and

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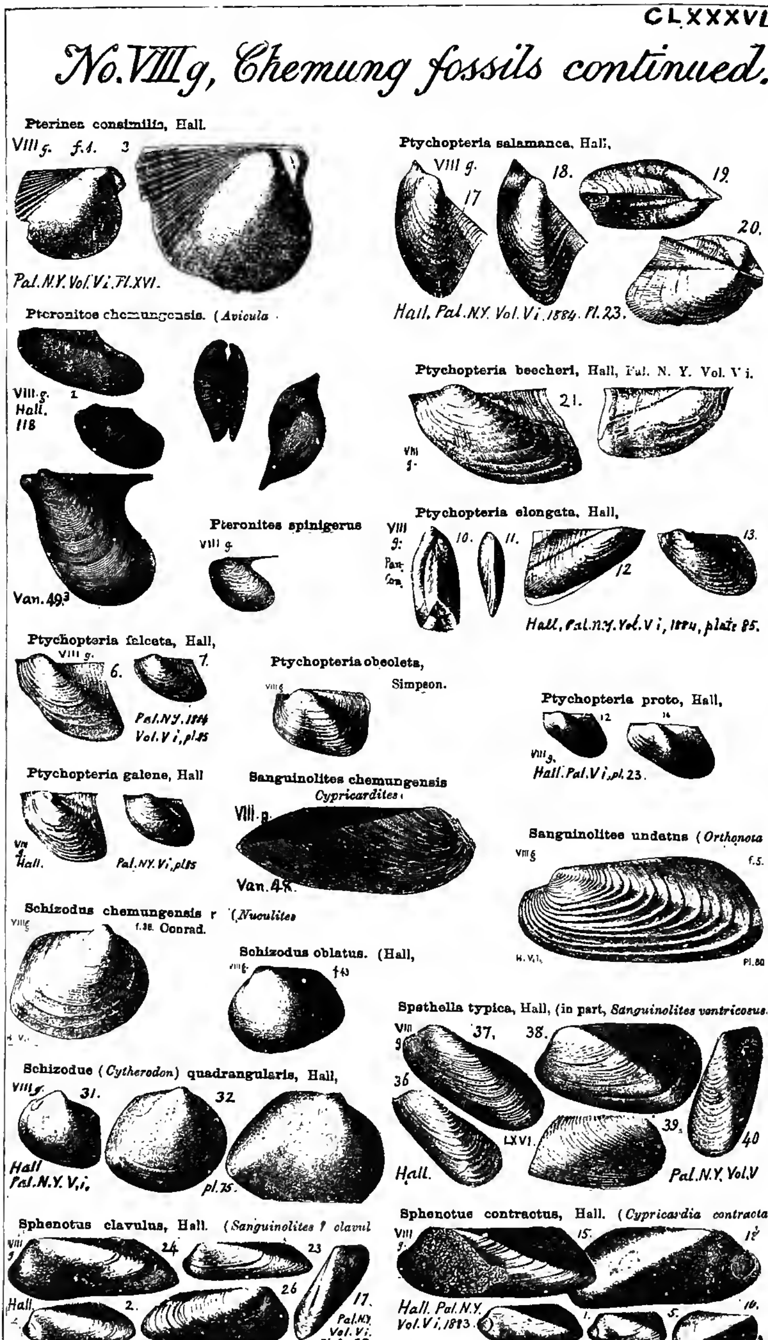
*Differs from *dumosa* by having a longer muscular depression (see fig. 3-c. cast of lower flat valve,) and not so definitely marked. Subrostral plates double, not single as in *dumosa* (see the small tooth each side of the beak, and larger than in other *Atrypas*. *A. reticularis* and *A. dumosa* are hard to distinguish in common hand specimens,; but their casts show the difference, as is the case with other *Atrypas*. Resemble also closely *A. prisca*, *A. affinis* etc., of earlier formations.

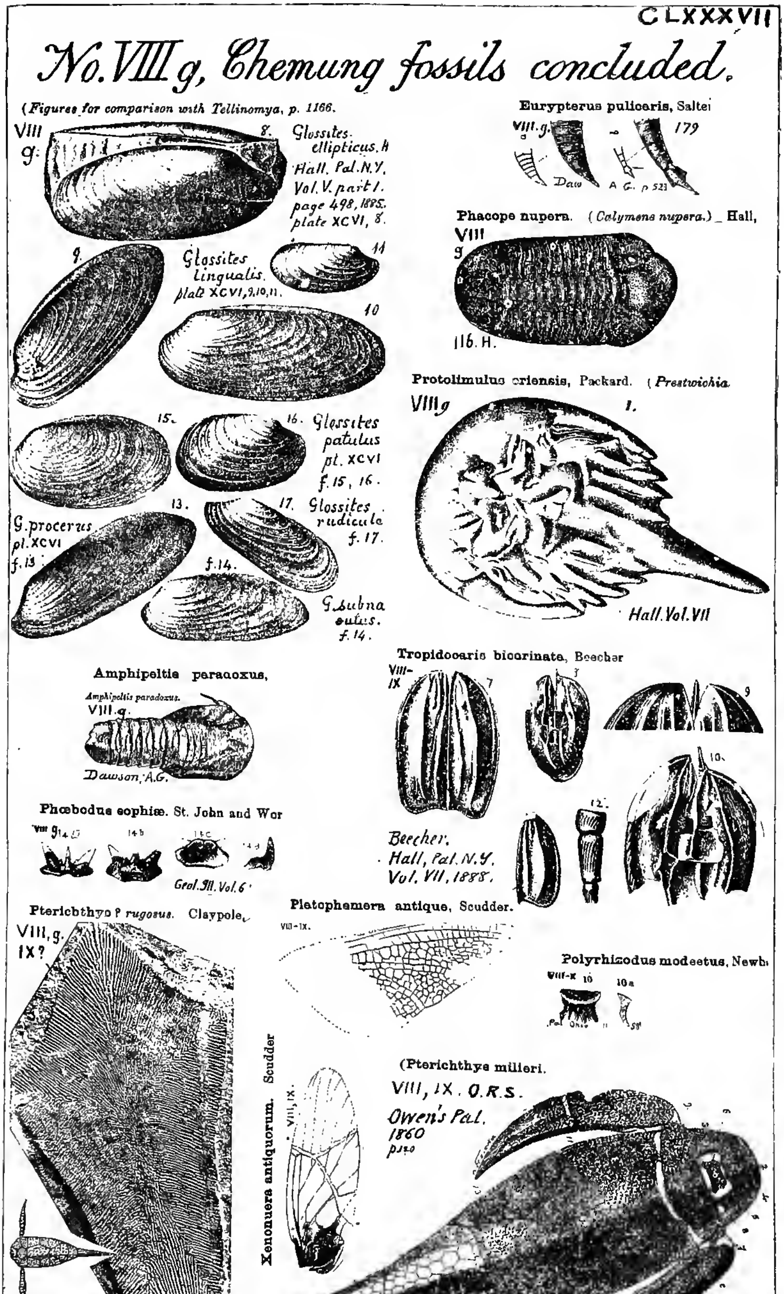
† So called because at first identified with that English shell of Phillips.

‡ Besides these, Vanuxem recognized in his Chemung belt at Port Crane, etc. the Hamilton brachiopod shells *Tropidoleptus* (*Strophomena*) *carinatus* and *Atrypa plebeia*. The Hamilton shells *Chonetes* (*Strophomena*) *lineata* and *Strophomena umbonata*, Van., seem generally distributed through the formation in Vanuxem's district of middle New York. A good collecting ground in Eastern New York is Sandberg creek on the Sullivan-Ulster line, 1½ m. from Red bridge, where *Spirifera prolata* and various lamellibranch shells occur (Mather, 1843, p. 320).


CLXXXVI.
No. VIII g, Chemung fossils continued.
Pterinea consimilis, Hall.
VIII g. f. 1. 3
Pal. N.Y. Vol. V i. Pl. XVI.
Ptychopteria salamanca, Hall,
VIII g. 17 18. 19. 20.
Hall, Pal. N.Y. Vol. V i. 1884. Pl. 23.
Pteronites chemungensis. (Avicula
VIII g. 1 Hall. 118
Van. 49.3
Ptychopteria beecheri, Hall, Pal. N. Y. Vol. V i.
21.
VIII g.
Ptychopteria elongata, Hall,
VIII g. 10. 11. 12 13.
Hall, Pal. N.Y. Vol. V i, 1884, plate 85.
Pteronites spinigerus
VIII g
Ptychopteria falcata, Hall,
VIII g. 6. 7.
Pal. N.Y. 1884 Vol. V i, pl. 85
Ptychopteria obsoleta,
Simpson.
VIII g
Ptychopteria proto, Hall,
12 14
VIII g.
Hall. Pal. V i, pl. 23.
Ptychopteria galene, Hall
VIII g. Hall.
Pal. N.Y. V i, pl. 85
Sanguinolites chemungensis
Cypricardites
VIII g.
Van. 48.
Sanguinolites undatus (Orthonota
VIII g
f. 5.
H. V, i,
Pl. 80
Schizodus chemungensis (Nuculites
VIII g
f. 38. Conrad.
Schizodus oblatus. (Hall,
VIII g.
f. 43
Spathella typica, Hall, (in part, Sanguinolites ventricosus.
VIII g
37, 38. 36 39. 40
LXVI.
Hall.
Pal. N.Y. Vol. V
Schizodus (Cytherodon) quadrangularis, Hall,
VIII g. 31. 32
Hall Pal. N.Y. V, i.
pl. 75.
Sphenotus clavulus, Hall. (Sanguinolites ? clavul
VIII g 24 23 26 2. 17.
Hall
Pal. N.Y. Vol. V i. Plate 66
Sphenotus contractus, Hall. (Cypricardia contracta
VIII g. 15. 12
Hall. Pal. N.Y. Vol. V i, 1883.
1. 5. 10.

many fine rays (see the bottom corner of Plate CLXXXIV above).—*Lyriopecten* (*Avicula*) *tricostatus* with ribs of three sizes.—*Pterinea* (*Avicula*) *longispina* 1½ inches long; with beak projecting far beyond the hinge line at one end; scarcely any front wing ; small hind wing running out into a very long straight spine, usually broken off ; surface concentrically lined ; sheil so diagonal and rounded as often to hide the spine ; not uncommon in the brown sandstone beds.—*Pteronites* (*Avicula*) *spinigerus*, living in company with the last, but much smaller.—*Pteronites chemungensis*, sometimes so compressed by the rock that its front wing can scarcely be seen. In the soft olive green shale of Steuben county specimens do not show radiating lines ; those from other places in New York do.—*Avicula acanthoptera* in the olive green shales of the Genesee river has a spine to its hind wing ; and its beak is nearly at its front end. These shells can be seen reduced from Hall's figures on Plate CLXXXV above.

The prevailing species of lamellibranch shells in the *olive green shales* of Rockville and Phillipsburg on the Genesee river are the following :—*Aviculopecten* (*Pterinea?*) *suborbicularis*, with almost no wings ; beak in center of hinge ; many (somewhat wavy) ribs, with smaller ones between them towards the margin ; the shell roughened with concentric wrinkles.—*Aviculopecten* (*Pecten*) *duplicatus*, with wings nearly equal ; many ribs, crossed by fine concentric lines. doubled and rough toward the margin. This marks the species, which is somewhat like Sowerby's *Pecten plicata*.—*Aviculopceten* (*Lima*) *rugostriatus ;* so called because its surface is made rough by its many strong fine ribs (becoming more numerous as they approach the margin) crossed by wavy raised plate edges.—*Aviculopecten* (*Pecten*) *cancellatus ;* like the last ; but with smooth, not rough radiating, and concentric lines, which cover the whole surface with a multitude of little squares.—*Aviculopecten* (*Avicula?*) *signatus*, recognizable by its surface, marked by sharp concentric lines or lamellæ.—*Aviculopecten* (*Pecten?*) *convexus ;* peculiar for its thickness (roundness) a small pretty shell easily distinguished.—*Aviculo-*


CLXXXVII
No. VIII g, Chemung fossils concluded.
(Figures for comparison with Tellinomya, p. 1166.
Glossites ellipticus, H. Hall, Pal. N.Y. Vol. V. part I. page 498, 1885. plate XCVI, 8.
Glossites lingualis. plate XCVI, 9, 10, 11.
Glossites patulus pl. XCVI f. 15, 16.
G. procerus pl. XCVI f. 13
Glossites rudicula f. 17.
G. subnasutus. f. 14.
Eurypterus pulicaris, Salter
Phacops nupera. (Calymene nupera.) _ Hall,
Protolimulus eriensis, Packard. (Prestwichia.
Hall. Vol. VII
Amphipeltis paradoxus,
Amphipeltis paradoxus.
Dawson, A.G.
Tropidocaris bicarinata, Beecher
Beecher. Hall, Pal. N.Y. Vol. VII, 1888.
Phœbodus sophiæ. St. John and Wor
Geol. Ill. Vol. 6
Pterichthys ? rugosus. Claypole.
Platephemera antiqua, Scudder.
Polyrhizodus modestus, Newb.
Xenoneura antiquorum. Scudder
(Pterichthys milleri.
VIII, IX. O.R.S.
Owen's Pal. 1860
Pterichthys Miller

pecten (*Pecten?*) *dolabriformis* (axe shape) resembles the last (*A. convexus*) but is much less convex, more oblique and with small front and large hind wings and surface marked by fine radii, crossed by fine concentric lines.—*Aviculopecten* (*Pecten*) *striatus;* evenly curved with fine radiating striæ, differing thus from all other *Aviculopectens*, wings nearly equal.—*Pernopecten* (*Pecten?*) *crenulatus*, with its hind wing extending down the side of the shell more than half way to the base; front wing short; hinge-line wavy (crenulated) or set with cross ribs; radiating and concentric lines both faint, or absent.—*Pernopecten* (*Lima*) *glaber;* an oblong, fat little shell, with a very short hinge line, small ears; surface smooth, with a few scarcely visible concentric waves. It may be known by its narrowness just below the hinge line, and by its very smooth surface.—*Pernopecten* (*Lima?*) *obsoleta*, with a hinge line crenulated, which is against its being a *Lima*.*

The following *lamellibranch* shells are assigned to the *Chemung* formation in Prof. Hall's Ms. list of types in the State Museum at Albany (1886):—Actinopteria perstrialis, tenuistriata; Amnigenia catskilliensis (now placed in the Oneonta sandstone); Aviculopecten cancellatus, duplicatus, rugastriatus, striatus, tenuis; Byssopteria radiata; Crenipecten ampla, crenulatus, glaber, obsoleta; Edmondia philipi, rhomboidea, subovata, tumidula; Glossites lingualis, patulus, subnasutus; Glyptocardia speciosa (also Hamilton); Goniophora subrecta (4 other sp. in Hamilton); Grammysia communis, elliptica, subarcuata, undata (11 other sp. in Hamilton); Leiopteria torreyi; Leptodesma agassizi, alatum, arciforme, billingsi, cadmus, clitus, creon, corydon, demus, disparile, extenuatum, flaccidum, hector, jason, lesleyi, lichas, longispinum, lysander, maclurii, matheri, medon, mortoni, mytiliforme, nereus, orodes, orus, patulum, pelops, phaon, potens, propinquum, protextum, quadratum, robustum, rude, shumardi, sociale, spinigerum,

* In eastern New York there are few good collecting grounds for Chemung fossils; but at Sandberg creek can be got in great abundance *Pterinea chemungensis*, *Pterinea flabella*, *Avicula tricostata*, and *Cypricardita chemungensis* (Mather). *Languinolites chemungensis* was got at several places mostly at the small bridge on the Lisle-Birmingham road.

stephani, truncatum (the Hamilton has only one species, rogersi); Lyriopecten priamus, tricostatus; Lunulicardium fragile (another in Hamilton and another in Marcellus); Macrodon chemungense (the Hamilton species is hamiltoniæ); Microdon (*Eodon*) gregarius (one of 4 Hamilton species which alone survived in New York); Modiola (*Mytilops*) præcidius; Modiomorpha chemungensis (a variety of the Hamilton *subalata*, one of Conrad's four), quadrula, subangulata; Mytilarca carinata, chemungensis, lata, simplex (N. B. oviformis is Hamilton; arenacea is Schoharie); Nucula diffidens, (6 other sp. in Hamilton); Palæanatina negusta, typa; Palæoneilo filosa, brevis (one survival of 9 sp. Hamilton); Prorhynchus quadratum; Prythyris exuta (lanceolata is Hamilton); Pterinea flabella (also Hamilton), chemungensis, consimilis; Pterinopecten crenicostatus, dispandus, neptuni, striatus, suborbicularis; Ptycopteria elongata, eucrate, falcata, proto, salamanca, sao, thalia, thetis; Schizodus chemungensis and its variety quadrangularis, oblatus, rhombius; Spathella typica; Sphenotus clavulus, contractus (other sp. are Hamilton).

CHAPTER LXXXXV.

Prof. Stevenson's views of the upper limits of the Chemung formation and its relationship to the Catskill and Carboniferous.

Before proceeding further it is necessary to discuss a moot point of nomenclature which must embarrass the readers of the Reports of Prof. Stevenson on Bedford and Fulton counties, and Prof. White on the northeastern counties and Huntingdon. And I cannot do this better than by quoting the words of Prof. Stevenson's address on the subject before the Section of Geology of the A. A. A. S. at its Washington meeting, August, 1891. In this address he gives his reasons for rejecting Prof. White's "Chemung-Catskill Passage beds."

My own opinion is that these intermediate passage beds can very well be formulated as a separate formation in the series, and well deserve a separate name, and I propose for them the name of the *Venango formation.* For although it is not proven that the interval between the Allegrippus and Lackawaxen conglomerates is the very interval between Carll's Venango Third and First oil sands, yet as Ashburner has shown in his McKean and Cameron reports (R, R2) the increase of the red rocks southeastward renders this a very probable hypothesis ; and the general horizon is undoubtedly the same. There is no improbability that the interval of 1000′ in Huntingdon county should get diminished to 300′ in Venango county. The chief objection comes from the absence of any known representative of the Venango Second Oil Sand in Middle Pennsylvania. Prof. Stevenson's argument is chiefly based on fossils. But Prof. White's classification is also based on fossils. On the one hand the Chemung shells pass up into the Catskill. On the other hand the Catskill fishes descend into the Chemung.

Nothing could better express the insufficiency of Palæontology for classifying sedimentary formations.

Prof. Stevenson says: "In the southwestern portion of Virginia the Devonian is represented only by black shale belonging at the base of the Hamilton; but within a few miles the Hamilton shows a greatly increased thickness, while between it and the Lower Carboniferous there are 350 feet of rock carrying Chemung fossils to within fifty feet of the top. The fossils are most abundant in a red or bluish rock with conchoidal fracture, which is the same in all respects physically with some non-fossiliferous beds higher up in the section. Within sixty miles along the strike this 350 feet has developed into a great series with well marked horizons in the lower part, while the upper part has become flaggy with not a few massive beds. The succession now is, the thicknesses being estimated:

1.	Not fully exposed, containing much red sandstone, . .	700′
2.	*Conglomerate,*	49′
3.	Shales and sandstone, ...	1000′
5.	Shales and flags, ...	1500′
4.	*Conglomerate,*	30′

But the No. 1 of the section contains grey beds in the lower portion which in some localities have yielded Chemung mollusks at not less than 300 feet above the conglomerate, while on New river, Va., where the thickness is somewhat greater, the Chemung forms were seen at about 500 feet above the conglomerate. But the reddish beds which prevail toward the top seem to be non-fossiliferous. The tint of these beds becomes more and more pronounced toward the northeast, until in Catawba mountain, somewhat more than twenty miles southwest of James river, they have the dismal red and greenish color so characteristic of the series along the Potomac. And yet, in McAfee's gap, only eight miles northward, *Spirifera disjuncta* and some other forms of Chemung type occur very near the top of the series, within a few feet of the Vespertine (Pocono) sandstone.

"The other parts of the section can be observed at many places; the Upper Conglomerate contains flat pebbles, which frequently show the longer axis vertical to the plane of bedding; No. 3 contains concretionary sandstones passing downward into shales, with brown blue and red to deep red flags and flaggy sandstones. Chemung mollusks are especially abundant near the top. The lowest division consists of flags and shales, olive, gray, yellow, blue and drab, with but few fossils.

"This is the section to James river, somewhat more than 150 miles from the Tennessee line. Details of measured sections made in recent years between the James and Potomac rivers, a distance of not far from 200 miles, have not been published; but we need not wait for detailed measurements in this interval. Observations by the writer and by others at many localities have proved the section persistent; and the same succession is shown along the Baltimore and Ohio railroad as it follows the Potomac river. Of course there are variations in structure; Mr. N. H. Darton tells me that the conglomerates are wanting in the section near Staunton, Virginia, but this is merely local; they are present elsewhere. Farther north, the upper beds or Catskill have an increased proportion of shale, often blood-red, and the sandstones show a more marked conchoidal fracture, while the whole section has a greatly increased thickness.

"The Pennsylvania line is reached but a few miles north from the Potomac along the outcrop. Crossing that line, one enters Fulton county, where the succession is:*

1. Catskill:	Shales, ...	1600	
	Sandstone and shale, ...	2100′	
			3700′
2. Chemung:	Shales, ...	1000′	
	Upper Conglomerate, ...	10′	
	Shales and sandstone, ...	950′	
	Lower Conglomerate, ...	10′	
	Shales and flags, ...	1850′	
			3820′

"The close resemblance to the Virginia section is apparent at once, the most notable change being simply the great increase in thickness of the upper portion. The upper

* Geology of Bedford and Fulton counties. J. J. Stevenson, Harrisburg, 1882, pp. 73, 75, 82. I have re-arranged the section somewhat, placing the line between Chemung and Catskill 200 feet higher than in the original. [This foot note and all those which follow are by Prof. Stevenson.—J. P. L.]

Catskill consists for the most part of soft deep red shales with occasional sandstones; but the lower Catskill is made up of brownish or greenish to red cross-bedded, almost laminated sandstone, often looking as though it were worm eaten. Sometimes a large fragment remains on a hill top resembling much a pile of thin boards. Occasionally more massive sandstone prevails, as along the Juniata river in central Bedford county of Pennsylvania, where no tendency to lamination was seen. The Catskill appears to be wholly non-fossiliferous along the eastern outcrop from central Virginia into New York.

"The absolute limit between Catskill and Chemung is indeterminable, for the passage from one to the other is practically imperceptible at most localities; the line drawn at any locality, whether on stratigraphical or palæontological grounds, is almost certain to be unsatisfactory at any other. In Fulton county, however, a marked lithological change occurs about 1000 feet above the Upper Chemung Conglomerate, for there the alternations of red and yellow shales cease and the flaggy, almost laminated red sandstones begin. The last horizon of Chemung mollusks was found at 200 feet lower, where, at approximately 800 feet above the conglomerate, the writer originally drew the line between the two groups.

"The interval between the conglomerates is filled with yellow to red shales and gray, brown, blue or red sandstones; the red beds form an insignificant portion of the section, but such as are present are strikingly like Catskill, for the shales are are often bright red and the sandstones cross-bedded or in thin flags. Many of the beds in this interval are richly fossiliferous and the important horizons of Chemung lamellibranchs are at but a little way below the Upper Conglomerate. The lowest beds of the Chemung are shales and flags; the shales overlying the flags are yellow, gray, olive, dark brown and reddish; while the flags, which doubtless represent the Portage of New York, are almost wholly olive, and, unlike the overlying shales, appear to be very sparingly fossiliferous.

Beyond Fulton county northward into New York, we must depend almost wholly upon the work of Prof. I. C. White, who has demonstrated the stratigraphical relations of the beds under consideration to those of the Catskill area of New York, and has told the story with such clearness that there is no opportunity for any one to cavil. His grouping of the rocks, however, differs from that already given; he prefers to include as Catskill all beds down to 100 feet below the Upper Conglomerate, which is the lowest horizon at which he found fish remains; he regards as transition the beds below that fish bed to the lowest red bed, 150 feet above the Lower Conglomerate, and applies to them the term Chemung-Catskill; while the remaining beds of the section are taken by him to represent the Chemung and Portage of New York. He identifies the Upper Chemung Conglomerate of Fulton county with his Lackawaxen Conglomerate of the New York border and he gives the name of Allegrippus to the Lower Conglomerate.

"The succession in Huntingdon county,* Pennsylvania, is:

1. Catskill,		2500′
2 Chemung:		
1. Haun's Bridge group,	1000′	
2. *Lackawaxen Conglomerate,*	20′	
3. Sandstones and shales,	1000′	
4. *Allegrippus Conglomerate,*	5′	
5. Shales and flags,	3250′	
	———	4675′

"The Haun's Bridge group consists largely of greenish gray sandy shales and flags with some red beds, and holds from bottom to top Chemung mollusks, some of which are very abundant.

"Professor White's measurments near Catawissa,† in Columbia county, Pennsylvania, about sixty miles further along the strike, show the section still persistent, the succession being:

* I. C. White in Geology of Huntingdon county, Harrisburg, 1885, pp. 92–104. As given here, Nos. 1, 2 and 100 feet of No. 3 of the Chemung belong to Prof. White's Catskill; the rest of No. 3, except 150 feet at the base, forms the Chemung-Catskill of the same author. All sections along this outcrop quoted from Prof. White, have been re-arranged in this way.

† The Geology of the Susquehanna River Region. I. C. White, Harrisburg, 1883, p. 57.

1. Catskill,		3230′
2. Chemung:		
1. Shales and sandstones,	923′	
2. *Lackawaxen Conglomerate,*	40′	
3. Shales and sandstone,	1180′	
4. *Allegrippus Conglomerate,*	10′	
5. Shales, sandstones and shaly beds,	2300′	
		4453′

"The Catskill exhibits little change in structure and, as before, appears to have no fossils aside from obscure fish remains. No. 1 of the Chemung is the same with the Montrose shales of Susquehanna county as well as the Haun's Bridge group of Huntingdon county. It consists, as it does further south, of variegated shales and sandstones, green and red predominating, and in the lower half has many beds carrying Chemung mollusks. I have drawn the line between Chemung and Catskill somewhat arbitrarily, where sandstone ceases to predominate, for there is no noteworthy physical change in character of the rocks anywhere above the Lackawaxen Conglomerate. That conglomerate is now irregular in structure, sometimes not conglomerate, but still containing fish-bones as it does further south. The fragments of bones are larger and in better preservation than at the more southern localities.

"The interval between the conglomerates contains some red beds, but as usual they form only a small part of the section, little more than ten per cent. of the whole. A bed containing fragments belonging, apparently, to *Holoptychius*, associated with *Pleurotomaria* sp. and *Lingula spatulata* was observed at 150 feet below the *Lackawaxen Conglomerate.* Vegetable remains are not wanting, for *Archæopteris hybernica* is abundant above the fish bed. The Allegrippus Conglomerate is no longer a constant member of the series, though occasionally it is recognizable without difficulty as a massive sandstone, sometimes containing flat pebbles.

"Thus far the section observed beyond the James river in Virginia has been persistent, the distance along the line of the outcrop being not far from 500 miles. In Columbia county, however, the interval between the conglomerates is no longer richly fossiliferous, while fossils reach to but

516 feet above the Lackawaxen instead of to 1000 feet in Huntingdon county. The section is still sufficiently distinct at Hartville,* Luzerne county, Pa., about twenty miles farther along the strike; but thence northeastward, changes in structure become marked and are accompanied by a still more rapid disappearance of animal remains, so that within a few miles such remains seem to be almost wholly wanting in beds above the place of the Allegrippus Conglomerate.

"Professor White's Pike county † section was measured along the Delaware river about fifty miles northeastward from the Catawissa locality and practically on the same line of outcrops. It illustrates the conditions in New York for the Delaware river there cuts across the Catskill mountain region. The succession is:

Catskill:		
Honesdale sandstone,	100	
Montrose sandstone,	125′	
Chemung:		
1. Montrose red shale,	100	
2. Greenish gray sandstone,	30	
3. *Lackawaxen Conglomerate*,	50′	
4. Greenish sandstone and shale,	300′	
5. Red shale,	50	
6. Delaware flags,	1000′	
7. New Milford shales and SS.,	75′	
8. Starucca beds,	600′	
9. Sandstones and sandy shales,	1850′	
		4055

"The highest beds of the Catskill, the Cherry Ridge shales, were not measured, but they add barely 150 feet, so that within little more than fifty miles the Catskill has lost almost 3000 feet, while the Chemung is but 400 feet thinner. But it should be noted that the upper portion of the Chemung has lost much, while the lower portion has increased greatly. The Allegrippus Conglomerate belongs at the base of the Starucca beds but it is not present. Even the Lackawaxen is no longer persistent as a conglomerate and in some localities it is not even massive.

"The most interesting feature of this section, character-

* White, *loc. cit.*, p. 196.

† Geology of Pike and Monroe counties. I. C. White, Harrisburg, 1882, pp. 73 and 94.

izing also those obtained along fragmentary outcrops in Carbon and Monroe counties, say twenty-five miles southeast of that which has been followed, is the apparent absence of animal remains from the whole series above the lowest member of the section, there being no trace aside from what seems to be fragments of fish-bones in breccias of the Honesdale sandstone.* *Archæopteris Jacksoni* is plentiful near the base of the Montrose shales.

"We have followed this section along practically one line of outcrop for nearly 600 miles, from the northern boundary of Tennessee into southeastern New York. Its persistence, stratigraphically, is remarkable, since variations in structure are inconsiderable until within thirty miles of the New York border; but serious changes of some sort occurred during the long period of deposit, for, in the extreme south, even the representative of the Montrose sandstone carries Chemung fossils, while in northeastern Pennsylvania and the immediately adjacent portions of New York, animal remains practically disappear above the horizon of the Allegrippus conglomerate.

"Let us now return to southern Pennsylvania and follow the section westward; but first let us re-label the Fulton county section giving to its parts the geographical names applied in the counties between that and the Delaware river, so that the relations of the different parts of the section may be remembered. It becomes:

Catskill:		
Cherry Ridge shales,	1600	
Montrose sandstone,	2100′	
		3700′
Chemung:		
1. Montrose red shales,	1000′	
2. Lackawaxen conglomerate,	10	
3. Shales and sandstones, including Delaware flags and Starucca beds,	950′	
4. Allegrippus Conglomerate,	10′	
5. Shales and flags, including Portage of New York,	1850′	
		3820′

*Mr. C. S. Prosser informs me that he has discovered some lamellibranchs in the Delaware flags and some Spirifers in the Honesdale sandstone, or possibly at the base of the Cherry Ridge shale.

"The thickness of the section diminishes rapidly toward the west, so that on the western border of Bedford county. near the Maryland line, the Cherry Ridge shales have almost disappeared and the total thickness of Catskill, including doubtless some of the Montrose shale, is but 1980 feet.* No outcrop is seen in the adjoining county of Somerset until the western edge has been reached, where, under the great anticlinal of Laurel Hill the Youghiogheny river has cut down to the Delaware flags. There the Montrose sandstone is present, but only a few feet thick; while at not more than three miles further west, on the other side of the anticlinal, the Catskill has disappeared and the Vespertine (Pocono) rests directly on the Montrose shale.

"The Chemung shows a similar decrease in the same direction; for, on the railroad section in western Bedford, the whole interval of Chemung and Hamilton is represented by a concealed space of 2630 feet, giving to the Chemung a thickness of somewhat more than 1800 feet. The exposures under Laurel Hill in the Youghiogheny and Conemaugh gaps suggest a continuance of the decrease, certainly in the upper portion. The gaps through Chestnut ridge, ten miles west from Laurel, afford the last exposures in this direction of any part of the Devonian on the eastern side of the basin; the section in the Conemaugh gap,† barely fifty miles in a direct line from Pittsburgh, is;

Ponoco,	443′
Montrose red shales,	125′
Lackawaxen Conglomerate,	20′
Shale and sandstone,	120′
Concealed to river,	150′

"The Montrose shale is composed of dull, grayish red shale and thin streaks of sandstone, carrying Chemung species up to within one foot of the Pocono. The Lackawaxen is characterized by flat-pebbles‡ as it is also on the

* Stevenson; Geology of Bedford and Fulton counties, p. 81

† Geology of Fayette and Westmoreland counties. J. J. Stevenson, Harrisburg, 1877, p. 291.

‡ An annoying error occurs in my report on the Ligonier Valley (Harrisburg, 1878). Some of the notes referring to this rock were copied under the Pocono and some of the Pocono transferred to this, so that this conglomerate is described as not containing flat pebbles.

National road in Fayette county, where some of the larger pebbles are felsyte-porphyry. Excavations made since these measurements were obtained show that there is much dull red shale below the Lackawaxen, especially in the concealed portion. The interval from the top of the Pocono to the Lackawaxen is 568 feet; in the deep boring at Pittsburgh it is given as 519 feet.

"Mr. J. H. Carll has tabulated the oil-well records in the western oil-bearing counties of Pennsylvania and we must depend largely upon his work as we follow the series northward inwestern Pennsylvania; though one may sometimes fail to accept his identifications, yet all must acknowledge the patience with which he has worked and the excellence of his results.

"At Washington, about thirty miles southwest from Pittsburgh, the interval to the Lackawaxen from the top of the Pocono is 518 feet, and the rock is termed by Mr. Carll,* the "Gas Sand." The section there is:

Pocono (Shenango sandstone of White),	152′
Interval,	366′
Lackawaxen Conglomerate,	20′
Interval,	87′
Gantz oil sand,	40,

"The Pocono has become less coarse. At Pittsburgh it contains much shale, while in Washington county its sandstone is often less than 150 feet thick.

"Mr. Carll recognizes in the Gantz sand, the upper or first of the Venango group of oil-sands which consists of three well-marked sandstones separated by shales and showing few variations in Venango county. It is not easy, however, to accept this identification after a careful study of his sections as tabulated in the Annual Report for 1886,† and I am compelled to regard the Upper Gas Sand of Weirick's well as the first oil-sand of Venango and as the Lackawaxen. The distribution and variations of the Venango group are shown in the very numerous records of oil-wells which Mr. Carll has preserved and published in

*Carll in Ann. Report of 2d Geol. Survey of Pennsylvania for 1886, p. 545. See plate 5, Figs. 20 and 21.

†See Fig. 21 of plate 5.

his volumes on the western counties of Pennsylvania. A section on Thorn creek * in Butler county, at about thirty miles northward from Pittsburgh gives:

Shenango sandstone (of White):

Interval,	395′
[*Lackawaxen*] first Venango oil sand,	45′
Interval,	420′
[*Allegrippus*] third Venango oil sand,	46′

"Seven years ago, Professor White asserted that the first oil sand is the same with his Lackawaxen and suggested that the Allegrippus might prove to be the same with the Third Venango. There is no room for doubt respecting the accuracy of these surmises. The interval between the sands is not far from what we should expect, for in western Bedford it is not more than 600 feet and the decrease in the upper part of the column continues westward to the last exposure under Chesnut ridge. Some red rock occurs in this interval at Pittsburgh and at Petrolia in eastern Butler as well as at Edenburg, twenty miles farther east in Clarion county. Red shales, from sixty to more than 100 feet thick overlie the Lackawaxen at many places in Butler county, though occasionally they are separated by a few feet of variegated shale. A section on Bullion creek,† in Venango county, about thirty miles north from Thorn creek, shows 100 feet of red rock immediately over the Lackawaxen or first oil-sand and fifty-five feet of red rock in the 215 feet interval between that and the Allegrippus or third oil sand. The distance from the Pocono here to the Lackawaxen is 385 feet, almost the same as in Brady township and on Thorn creek of Butler county.‡

"It is unnecessary to go into further detail respecting the features of the Venango group as the variations aside from those of thickness are inconsiderable and they are all shown in full in Mr. Carll's several reports.

"The whole series. comes to the surface again in Craw-

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* Carll in Report for 1886, p. 650. See Fig. 19, of plate 4. I have condensed the section and inserted the names of the sands.

† Carll in *loc. cit.* p. 647. See plate 3, Fig. 14.

‡ Carl in Report for 1886, p. 650. See fig. 19, of plate 4. I have condensed the section and inserted the names of the sands.

ford and Erie, the northwest counties of Pennsylvania, where the subdivisions have been worked out in great detail by Professor White. I give his generalized section*

Pocono:		
1. Shenango sandstone,	25′	
2. Meadville shale and limestone,	66′	
3. Sharpsville flags and limestone,	64′	
4. Orangeville shale,	75′	
5. Corry sandstone,	20	=250′
Chemung:		
1. Cussewago shale and limestone,	37	
2. Cussewago sandstone,	25′	
3. Riceville shales,	80′	
4. (*Lackawaxen*) first oil sand,	20′	
5. Shales with second sand,	260′	
6. (*Allegrippus*) third oil sand,	30	
7. Lower Chemung,	325′	
8. Girard,	225′	
9. Portage,	475′	=1477

somewhat condensed and differently divided:

"Professor White placed the whole section to the base of the Cussewago in the Pocono or Lower Carboniferous, though seemingly with some hesitation respecting the lower members. The Corry sandstone appears to be the representative of the Berea of Ohio. The Riceville shales are equivalent to the red rock of Butler and Venango as well as to the Montrose red shales of the eastern sections. Typical Chemung forms occur here at many places up to within fifteen feet of the Cussewago sandstone. The Lackawaxen is seldom coarse in northwestern Pennsylvania. The Allegrippus, or third oil sand, is the persistent stratum in this region and the one possessing economic importance. Professor White gives good reason for indentifying it with the Panama conglomerate of New York. Professor White found the same section in Warren county at Tidioute, twelve miles east from the Crawford line, and he regards the *Coccosteus* bed at Warren as the same with the Lackawaxen or First Venango oil sand. Mr. Carll's section at Great Bend,†, on the eastern edge of Warren county, is of

* Geology of Crawford and Erie counties. I. C. White, Harrisburg, 1881, pp. 66–119.

† *Loc. cit.*, p. 641.

interest as showing the appearance of the "Catskill type," as he terms it, there being above the Riceville shales, eighty-eight feet of greenish gray sandstone with olive and red shales; so that somewhere between Tidioute and Great Bend the typically Catskill characteristics appear in the upper part of the section. Chemung fossils are found in the Riceville shales or Montrose red shales, and *Sanguinolites* occurs in the Lackawaxen.*

"Meanwhile a noteworthy change has occurred below the Lackawaxen, for though 327 feet of rock are shown, yet the Allegrippus or Third sand is not reached; so that we are prepared for the condition shown by Mr. Ashburner's generalized section of McKean county, next east to Warren along the northern border of the state. There we find †

Pocono,	250′
Catskill,	250′
Chemung,	1990′

the Catskill consisting of red and gray slate, shale and sandstone" at Smethport, thirty miles east from Great Bend in Warren county. The Chemung is triple and its upper division is itself distinctly triple, consisting of:

Gray shale and sandstone,	350′
Red and gray shales and sandstone,	300′
Gray shales and sandstone,	650′

the lowest beds resting on the Bradford oil sand, which is Mr. Ashburner's Middle Chemung. Typical Chemung mollusks occur in the highest beds of the Chemung and some species appear to have persisted into the lower portion of the beds assigned to the Pocono. This abrupt thickening of Chemung and Catskill is precisely what should be expected here to accord with the conditions along the southern border of the state.

"The sections in Potter county, that adjoining McKean at the east, are incomplete and our knowledge of the structure is far from being satisfactory. Mr. Ashburner made some examinations in the western part of the county which

* Geological Report on Warren county. J. H. Carll, Harrisburg, 1883, p. 302.

† Geology of McKean county, etc. C. A. Ashburner, Harrisburg, 1880, p. 43.

were merely incidental and suffice only to show that the "Catskill type" of rock increases in thickness eastward just as it does toward the southeast, there being 370 feet of red, gray and green shales and sandstones overlying the uppermost subdivision of his McKean county Chemung.* He finds some red in his Chemung as well as in the overlying Pocono. Fish beds occur in his Catskill as well as in the upper part of his Chemung. No information is given respecting distribution of molluscan remains, but on the eastern side of Potter, Chemung forms extend far up into the red beds, for just over the border in Tioga county Chemung forms are found at more than 300 feet above the first red beds.†

"The condition in Tioga and Bradford counties, those next at the east, is sufficiently clear. Prof. White's incidental studies in those counties make it possible to utilize Mr. Sherwood's work and at the same time to gain a good understanding of the work done by Professor Hall and Mr. Vanuxem more than fifty years ago. The section near Blossburg, in Tioga county, gives a good starting point.‡

Pocono, ...	573′
Red shales, green and gray sandstones and concealed, . .	830′
Fish conglomerate (*Holoptychius bed*), ...	2′
Red shale and sandstone, ...	200′

"The thickness of the rocks in the vicinity of Blossburg has been much underestimated by other observers. All the beds of the section below the Pocono have been regarded by authors as Catskill; but at ten miles farther down the Tioga river, three miles below Mansfield, Chemung fossils have been found by Mr. Sherwood§ in a calcareous rock, only 165 feet below the bed taken as the base of the Pocono in Professor White's section and therefore at more than 950 feet above the lowest red beds in that section. At a little way farther east, Mr. Sherwood found great abundance of fish remains with shells and fragments

* *Loc. cit.*, pp. 77–78.

† A. Sherwood in Report of Progress in Bradford and Tioga counties. Harrisburg, 1878, p. 86.

‡ Geology of Susquehanna and Wayne counties. I. C. White, 1881, p. 72.

§ Sherwood; *loc. cit.*, p. 79.

of plants in the *Holoptychius* bed; a calcareous bed at 84 feet lower down contains abundance of well-known Chemung forms, while red beds continue in alternation with gray beds for 150 feet lower down in the column. In 1839, Professor Hall connected his New York work with Pennsylvania at Tioga, eight miles farther down the river, where he found the upper members of the Chemung passing under the Old Red Sandstone, whose thickness he estimated at 400 feet. It is sufficiently clear that the red beds, including the Fish Bed, were regarded by him as belonging to the "Old Red Sandstone."

"The McKean county section can be recognized without difficulty in Tioga county despite the change in character of the rocks; for the middle division of Mr. Ashburner's Upper Chemung finds its equivalent in the "Mansfield Beds" of Lesley, containing three ore beds near Mansfield, the second of which is the celebrated *Holoptychius* bed. The base of the red and gray group in McKean is at 900 feet below the Pocono while in Tioga county the *Holoptychius* bed is at 830 feet. At the same time, the structure so well worked out by Professor White in Susquehanna county can be recognized with less difficulty than that of McKean. Eastward from the Tioga river, fossils become rarer in the upper part of the section; Mr. Sherwood states that no fossils occur in the Towanda basin of Bradford county until a bed is reached at 800 feet below the Pocono.*

"Professor White's work in Susquehanna and Wayne counties, was connected by him with that in Bradford, which lies between Tioga and Susquehanna. His section for those counties,† condensed and re-arranged is

Catskill:	
Cherry Ridge shales,	110′
Honesdale sandstone,	90′
Chemung:	
Montrose red shales,	180′
Paupack sandstone and shales.	

* *Loc. cit.*, p. 28.

† Geology of Susquehanna County and Wayne County. I. C. White, Harrisburg 1881, pp. 56, 58, 59, 73. In accordance with Professor White's suggestion (Geol. of Susquehanna R. Region, p. 52), I have omitted the upper 375 feet of the section.

New Milford flags and shales, . . .	585′
Shales and sandstones, ...	244′
"Mansfield Reds, ...	90′
[*Allegrippus*] Cascade Creek sandstone, ...	25′
Shale and sandstone, ...	120′

"The lower portions of the column are not exposed in these counties. The Paupack sandstone, immediately underlying the Montrose shales, occupies the position of the Lackawaxen conglomerate, but it is not seen as a conglomerate except in eastern Wayne on the border of Pike county. The Cascade creek sandstone is the same with the Falls creek sandstone of Bradford county and with the Allegrippus conglomerate of Bedford and Huntingdon counties, the Lower Chemung conglomerate of Fulton connty. A great part of the interval between the sandstones is represented farther east by the Delaware flags. For the most part, this is the section observed along the Delaware river in Pike county of Pennsylvania and in the adjacent portion of New York; and the Honesdale sandstone is the Montrose sandstone of Vanuxem.* Professor White made diligent search for fossils, but no mollusks were found at any horizon more than 130 feet above the Allegrippus; but Chemung fossils are sufficiently abundant below that rock *Archæopteris jacksoni* occurs in the Paupack or Lackawaxen.

"We have come once more to the Delaware river, the last point reached in the tracing of the easterly outcrop. Clearly the series is one; the middle portion, that between and including the two conglomerates, is evidently persistent all the way round, except, perhaps, in McKean and Potter counties of Pennsylvania where, however, the difficulty lies most probably not in absence of the sub-group, but in the absence of records.

"The serious question now arises—How shall this great column, with a maximum thickness of more than 7000 feet, be divided and what value shall be assigned to the divisions? Before undertaking to answer the question, let us recall the signification of the terms Catskill and Chemung as originally employed.

"Mather in the annual report as well as in his final re-

* Annual Report of N. Y. Survey for 1839, p. 381.

port * used the term "Catskill Mountain Series" to include all beds from the very highest rocks in the Catskill Mountains down to the Corniferous, thus making it equivalent to "Formations VIII, IX, X and XI of Prof. Rogers' Report on the Geology of Pennsylvania for 1838." "Catskill Group" was used first by Vanuxem in his final report, published in 1842,† though he had previously fixed the lower limit as may be seen by reference to the fourth report, where he takes the Montrose sandstone as representing the group. That rock rests directly on the Chemung group, whose upper limits are not well defined in the Fourth district of New York though sufficiently so in the Third. Its lower boundary appears to be distinct in both, so that the group consisted of the Chemung and Portage. But the Catskill group of authors is a variable quantity. By some, the whole mass in the Catskills proper has been taken as belonging to the group, by others, the first red bed is taken as the base of the group, while others still see the beginning in the first fish bed. No one of these limitations suffices, for each is purely local in character and cannot be applicable over a great area.

"Stratigraphically, the two groups as understood by Vanuxem are separable without difficulty. The Catskill, including under that name the Cherry Ridge shales of White and the Montrose sandstone of Vanuxem, is thoroughly persistent along the eastern outcrop from Greene county of New York to far beyond the James river in Virginia ; its variations in thickness along this line are, for the most part, very similar to those of the upper and middle divisions of the underlying Chemung. Westward and northwestward, however, the variations of the Catskill are unlike those of the Chemung. In southern Pennsylvania, the Cherry Ridge shales disappear within forty miles, while the Montrose sondstone thins out more slowly and does not disappear until Fayette county is reached ; there, however, the whole mass, 3700 feet thick in Fulton county is wanting. In northern Pennsylvania the decrease in thickness is

*Fourth Annual Report, p. 227. Geology of N. Y., Part I, p. 299.

† Geology of New York, PartIII, p. 186; 4th Ann. Rep., p. 381.

abrupt for a few miles, but the final disappearance of rocks of the Catskill type is in Warren county, just as in New York it is in Allegany county east from the Genesee river.* In southwest Pennsylvania the Catskill is wanting, because the rocks have thinned out; whether the disappearance in northwest Pennsylvania is due only to thinning out or to interlocking with rocks of different color cannot be determined in our present state of knowledge.

"The upper subdivisions of the Chemung, when followed westward, are found to vary much after the manner throughout. The *abrupt changes observed in the Catskill* had no predecessors in the Chemung, except in southwestern Virginia, where the whole series, Chemung and Catskill, as well as most of the underlying Hamilton and much of the overlying Pocono have disappeared. The Chemung section thus grouped:

Shales,
Sandstone,
Shales and sandstone,
Sandstone,
Shales and flags,

can be recognized not merely along the eastern outcrop from New York to far beyond New river in Virginia but also in western Pennsylvania many miles beyond the western limit of the Catskill beds.

"It is sufficiently clear that at the close of the time embraced in the Chemung group a physical change occurred, which though not observable along the eastern outcrop becomes very distinct within 100 miles westward or northwestward. During the whole of the Chemung period the subsidence was less and less rapid toward the west and northwest, though doubtless keeping pace there as at the east with accumulation of deposits, which in that direction became less in quantity and finer in grain, as the rocks at the west and northwest were not such as to yield much coarse material. But at the close of the Chemung, the subsidence became still less rapid toward the west and northwest so that the area in which Catskill was deposited became narrower

* Geology of New York, Part IV, p. 279.

toward the south.* It is altogether unnecessary to resort to the conception of elevation in western Pennsylvania or Virginia; indeed any such conception would be at variance with such evidence as we have. That region was not above water at any time so as to make the Catskill deposit in a closed sea; no subaërial erosion took place there after the close of the Chemung, for the thickness of Montrose shales in the oil-wells and in northwestern Pennsylvania, where they are Professor White's Riceville shales, varies immaterially from their thickness in Somerset county, where they underlie the western edge of the Montrose or Honesdale sandstone.

"But while making use of these variations in rate of subsidence as affording a convenient method of separating the Catskill and Chemung groups, we must not forget that, in by far the greater part of the area, the conditions exhibited in the Catskill are but a continuation and as it were an intensification of those existing in the Venango portion of the Chemung. The appearance of red rock with green and greenish gray sandstone begins in Pennsylvania very little above the Allegrippus conglomerate, and continues in irregularly increasing quantity to the top of the column, while in New York red rock makes its first appearance in the Portage.†

"The amount of red rock between the conglomerates varies greatly, being seldom more though often less than ten per cent. along the eastern outcrop, while at some places in western Pennsylvania it is much greater. The Montrose shales are largely red along the eastern outcrop, but they show not a little variation there; while at the west, they are sometimes wholly red and at others without any red beds whatever. Greenish gray and brown or reddish brown sandstone occurs in large proportion in the Catskill itself.

"All observers agree that the passage of Chemung into Catskill is so gradual that lithologically no absolute line of separation can be drawn in a great part of the Appalachian

* Because of the southwestward trend of the Appalachian land area.

† James Hall in 28th Annual Report of the Regents of the State Museum, 1876, p. 15.

basin. The bond between Catskill and Upper Chemung is even more intimate as far as structure goes than is that between the Upper Chemung and the Lower Chemung or Portage. As far as physical characteristics are to be depended on, the whole series is one, and the terms Catskill, Chemung, Portage, might well be taken as names of epochal divisions of the Chemung period.

"The palæontological record confirms this conclusion drawn from study of the stratigraphy. For the most part, the changes in general conditions were insignificant from the beginning of the Portage to the close of the Chemung; at all events the changes, in by far the greater part of the area under consideration, were not such as to interfere materially with the existence of the molluscan fauna known as Chemung, though as we have seen, there were circumscribed areas in which the conditions did prove very injurious to animal life.

"The Chemung and Catskill are very distinct palæontologically along the eastern outcrop in southern Pennsylvania. The Catskill, almost wholly red shale and red or greenish gray sandstones, appears to be wholly non-fossiliferous; but the Chemung carries its fossils to practically the top of the Montrose shales. The condition is unquestionably the same in northern Virginia. Near the Tennessee border the equivalent of the Montrose sandstone has Chemung fossils; at New river gap Chemung fossils were not found in the upper half of the interval between the Lackawaxen and the Pocono; in McAfee's gap in Roanoke county, proof is shown that *Spirifera disjuncta* survived all changes to the end of the Catskill; while at eight or ten miles southeast, in Catawba mountain, the whole succession of greenish gray sandstones seems to be absolutely non-fossiliferous; and this is the prevailing condition thence northward. It is evident then that from say twenty-five miles southwest of James river in Virginia to New York the group called Catskill by Vanuxem is either non-fossiliferous or practically so. But the Chemung group contains its characteristic species above the Lackawaxen Conglomerate in Virginia and along the eastern outcrop into Montour county of Pennsylvania ; so also in southern Pennsylvania * westward to where it passes beneath the surface beyond the final disappearance of Catskill in Fayette and Westmoreland counties; while in northwestern Pennsylvania and along the northern line of the state Chemung forms are present in the same upper horizon from the Ohio line eastward into Bradford county. In New York on the northwest border of the Catskills themselves Chemung fossils † occur abundantly above the Oneonta sandstone, which Vanuxem identified with the Montrose sandstone of Pennsylvania.

"A remarkable feature of the Chemung is the non-fossiliferous area of southern New York and the adjacent portion of Pennsylvania. Northward from Huntingdon county of Pennsylvania the upper limit of the Chemung fauna descends ; in Columbia county the upper half of the Montrose red shales yields no fossils, while in Carbon county no fossils were found until practically below the place of the Allegrippus Conglomerate ; and even in these lowest beds, fossils are rare and usually not well preserved. No molluscan fossils were found by Professor White in the Delaware river section until considerably below the place of the Allegrippus, whence downward 'the whole series is sparingly fossiliferous.' ‡ Even the remains of fishes are wanting aside from 'the occasional appearance of what appear to be fish-bone fragments in calcareous breccias.' A similar condition is observed as one comes eastward along the border of Pennsylvania and New York ; Chemung fossils reach the top of the group at the western border and in McKean county ; but in Tioga county the barren space at the top of the column is 165 feet ; in Bradford, 800 feet ; in Wayne, 1170 ; and in Pike, 2650 feet ; in each case inclusive of the Catskill which, however, does not exceed 300 feet even in Pike county.

"The area in which the lifeless portion of the column

* In my Report on the Geology of Bedford and Fulton counties, p. 81, I identified the Conglomerate of the Laurel and Chestnut ridge gaps with the Lower (Allegrippus) Conglomerate. The error was discovered too late for correction.

† James Hall in Science, 1880, p. 290.

‡ Geology of Susquehanna River Region, pp. 103 and 105.

reaches much below the horizon of the Lackawaxen Conglomerate, embracing parts of Carbon, Monroe, Pike and Wayne counties of Pennsylvania and Sullivan, Delaware and Green counties of New York, contains rather more than 4000 square miles, while the whole area under consideration is more than 30,000 square miles. To explain the absence of life is not easy ; it cannot be due merely to an agent which caused the redness or greenness of the beds, for in Huntingdon and Fulton counties of Pennsylvania the Montrose shales have many fossiliferous beds though having also many green and red beds. Besides, the Delaware section shows a great thickness of beds of other colors, which are equally without animal remains. It cannot be due to chemical conditions existing in a closed sea, for the successive subdivisions of both Catskill and Chemung can be traced directly into the lifeless area equally from the open sea at the west and along the Appalachian shore from the south, thus showing that no closed sea existed in that area. Even plant remains are rare, being found at but few localities ; and as a rule the specimens are imperfect, good specimens occurring at only a very few places. There is little room to suppose from the condition in which the plants are found that alternations of land, fresh and brackish water conditions caused the absence of animal life. It is certain that from the beginning of Oriskany to the end of Catskill, even during the formation of the Corniferous coral reefs, the Appalachian gulf was shallow everywhere. During the latter time, when subsidence did little more than to keep pace with the inflow of sediment, the area nearest to the region of great drainage, whence large streams with rapid flow poured their material into the shallow basin, would show muddy bottoms and muddy, more or less brackish water which would be unfavorable to animal life of Chemung types. As the Appalachian land became narrower southward, the untoward conditions are less marked in that direction. Within the portion of the area lying within southeastern New York and the immediately adjacent portion of Pennsylvania these conditions may have been begun as early as the Hamilton, as suggested by Professor Hall.*

"The molluscan fauna of the Chemung and Catskill is unquestionably marine. Even the mollusks found in New York above the Oneonta sandstone belong to the ordinary forms. Of course it is possible, even probable, that at the extreme northeast there were small areas at the mouths of large rivers where fresh water prevailed and fresh water mollusks lived; but positive evidence of this is wanting. The *Amphigenia* found in the Oneonta sandstone of New York may be a fresh-water form, but it occurs in the Montrose sandstone in southern Pennsylvania so far away from the old shore line that fresh-water conditions seem certainly improbable.

"The stratigraphical relations of the fishes have been generally misunderstood. The fishes exist, for the most part, not in the Catskill but midway in the Chemung; the celebrated *Holoptychius* bed is the second of the ore beds of the 'Mansfield Red' and belongs at but a little way above the Allegrippus Conglomerate, the Falls creek sandstone of Bradford county. It has yielded large numbers of fish remains at several localities and it contains marine fossils.† The *Coccosteus* bed of Warren county is taken by Professor White to be the same with the First Venango sand (Lackawaxen Conglomerate). Wherever the fishes are associated with any other form of animal life, that form is marine, so that the ordinary presumption should be that the fishes themselves are marine.

"A study of the fauna and its distribution shows us that, as far as any evidence exists, the conditions were marine from the beginning of the Chemung period to the close of the Catskill; that in the early Chemung or possibly in the Hamilton the conditions within northeast Pennsylvania and the adjacent portion of New York became unfavorable to the free development of animal life; and that as time went

* Science, 1880, p. 290. Prof. H. S. Williams makes the same suggestion in Bulletin U. S. G. S., No. 41, but I have mislaid the reference.

† Sherwood in Report on Bradford and Tioga, pp. 63, 65, 79, 80.

on, these conditions were gradually extended southward and westward, so that toward the close of the Chemung, they prevailed in Columbia county, fifty miles west from the Delaware river, and in Bradford county, about the same distance west from the outcrop line. Before the close of the Catskill they had reached southward beyond James river in Virginia but had not extended much farther west in Pennsylvania and New York. But while prevented from existing in the muddy shallows, the animals existed farther west in the basin beyond reach of the river silts. Just as soon as an opportunity was afforded by a lull in the untoward conditions, the active fishes found their way eastward again to be followed, if the interval were long enough, by the more sluggish mollusks as in New York and in Roanoke and Russell counties of Virginia.

"What are the relations of this great Chemung-Catskill group to the Lower Carboniferous?

"The Pocono or Vespertine or Lower Carboniferous sandstone, the lowest division of the Lower Carboniferous, is practically non-fossiliferous throughout central and southern Pennsylvania, the only animal remains thus far discovered being those of mollusks, seen by Professor White* in Bedford county, Pennsylvania, and those of fishes seen by Professor Stevenson† in Fayette county; but these have not been studied and their relations are still unknown. The upper beds of the Pocono become calcareous in southwest Virginia where the mollusks are unquestionably Lower Carboniferous. The plant remains, obtained in Pennsylvania, are for the most part imperfect, but an abundant flora exists near New River in Virginia, which has been collected by Mr. R. D. Lacoe. It has not been studied in detail, but enough has been ascertained to show that its facies is Devonian rather than Carboniferous,‡ The Lower Pocono in Pennsylvania, containing thin coal beds, may prove to be the same with the series near New river, which

*Geology of Huntingdon county, p. 81.

†Geology of Ligonier Valley, p. 57.

‡J. P. Lesley in a Dictionary of Fossils found in Pennsylvania and Elsewhere, Vol. III. Addenda, p. xiii.

disappears altogether before the state line is reached at the south.*

"The molluscan fauna of the Chemung shows no intimate relation to that of the Lower Carboniferous. True, not a few Carboniferous types make their appearance in the Chemung, but in like manner some Devonian types make their appearance in the Upper Silurian. The plant remains of the Chemung show somewhat greater affinity to the Carboniferous, but there is not enough of the material to justify positive conclusions in any direction; at the same time these plants are closely allied to the Erian flora of Canada, occupying a somewhat similar position in the general column.

"The physical break between Pocono and Catskill seems to be sufficiently well-marked at most localities along the eastern outcrop, as well as along the southern border of Pennsylvania; so that where Pocono and Chemung go beneath the surface they are sharply separated. The Pocono goes under in Fayette and Westmoreland counties of Pennsylvania as a sandstone containing very little shale; but when it reappears in northwestern Pennsylvania, in Crawford county, it is sandstone on top with much shale below. so that the separation from the underlying Chemung is by no means so distinct. Professor White, in making his correlations with Ohio, found difficulty in determining the equivalents of the Cleveland and Bedford shales of that state, which were regarded then as belonging to the Waverly or Lower Carboniferous. But Prof. Edward Orton, several years ago, found it necessary to place the Cleveland shales in the Devonian: and still more recently, Professor Herrick's detailed studies have shown that the Bedford shales carry the Chemung fauna, as was suggested many years ago by Professor Hall. But, beyond all doubt, the lower portion of the Pocono in Crawford county shows an

* It is worth noting here that during the study of Wayne and Susquehanna counties, Professor White placed the upper limit of Catskill nearly 400 feet higher in the column than he did in his later publications. It is not at all improbable that his original plane of division may prove to be the proper one for the whole eastern outcrop to beyond New river.

unexpected relation to the Devonian,* for at about two hundred feet below the Shenango sandstone, there is a persistent limestone, which, though non-fossiliferous in Crawford, carries many fossils in Warren and Venango counties. It is found also in McKean. The fossils from Warren and Venango have not been studied but Professor White says that one of the *spirifers* suggests *S. disjuncta.* Chemung forms occur at the base of the Corry sandstone, which Professor White thought to be the equivalent of the Berea grit of Ohio. In McKean county† Professor Hicks found Chemung forms passing up into the Mauch Chunk or upper division of the Lower Carboniferous and associated there as well as in the lower beds with 'Waverly forms,' seven Chemung species having been found with seven determined and eleven undetermined species regarded by him as of 'Waverly type.' Prof. H. S. Williams has shown, in his discussion on the Fossil Faunas of the Upper Devonian, ‡ that at some localities in southwestern New York and northwestern Pennsylvania species belonging to the Chemung fauna lingered even into the shales underlying the Olean conglomerate, which is the floor of the Coal Measures. It is sufficiently clear that while the passage from Devonian to Carboniferous along the eastern outcrop and for many miles west and northwest from it was marked by great physical changes, no serious disturbance occurred in the region of northwestern Pennsylvania and the adjoining portions of New York and Ohio, where the passage was so gradual as to permit the Chemung fauna to overlap that of the Lower Carboniferous. But the fact that at some locality or even in a somewhat considerable area the passage from Chemung to Carboniferous is not marked by abrupt change in sedimentation and by a sharp limitation of faunas is not a good reason for embracing Chemung in Carboniferous. Other portions of the Appalachian region might be selected which would afford material for very different generalizations.

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* White: Geology of Crawford and Erie counties, p. 88.

† L. E. Hicks in Report on Geology of McKean county, pp. 30–31.

‡ H. S. Williams: Bulletin of the United States Geological Survey, No. 41, Chapter IV.

"If continuity of sedimentation is to be accepted as of itself a good basis for grouping rocks, one would be compelled, within a considerable area of Virginia to include in one age all rocks from the Hudson river shales to the top of the Pocono, for there one finds no interruption except a streak of Lower Helberberg, so thin that only one observer has seen it in place,* though others have seen fragments of chert suggesting the presence of that group. Nor is the fact that there are localities where the passage is not marked by destructive fauna, necessarily a good reason for joining two consecutive groups. On such a basis one would have no difficulty in carrying the Carboniferous downward so as to include the Lower Silurian or upward to include the Pliocene. Thus, in northwestern Pennsylvania the Chemung fauna lingered into the Lower Carboniferous; in south central Pennsylvania and Maryland† Oriskany and Lower Helderberg fossils are mingled together in a transition bed. Ordinarly the break between Lower and Upper Silurian is well marked; but in southern Pennsylvania‡ the Hudson river forms occur sparingly in the Lower Medina, while in southwest Virginia § Hudson river fossils occur abundantly to within a few feet of the Upper Medina; so that even on the easterly side of the Appalachian basin it would be easy to prove no break between Lower and Upper Silurian, Upper Silurian and Devonian, Devonian and Lower Carboniferous, Lower and Upper Carboniferous. Dr. C. A. White ‖ has told us how the line between Palæozoic and Mesozoic disappears in the southwest; while, to not a few of us the gradual shading away of Mesozoic into Cenozoic brought a sufficiency of burdens in the past. General not circumscribed conditions must be taken as the basis of subdivision of the column. The separation between Lower Carboniferous and the Upper Devonian is too well marked physically as well as palæontologically over an im-

* Capt. C. R. Boyd, in personal communicaaion.

† Stevenson: Geology of Bedford and Fulton Counties, p. 86.

‡ 4 *Loc. cit.*, p. 92.

§ Stevenson: Proc. Amer. Phil. Soc. vol. XXII. p. 138; XXIV, p. 85.

‖ C. A. White: Address as vice president Section E. of A. A. A. S., 1889.

mense area to be ignored for any but the most cogent reasons.

"But may not the Catskill as well as some portion of the Chemung be contemporaneous with the lower beds of the Lower Carboniferous of Ohio? Professor Herrick‡ has shown that the base of the Lower Carboniferous there cannot come below the Berea Grit. He has shown also how intimately related the Bedford shale is to the underlying Cleveland-Erie, shale and that forms of Lower Carboniferous type made their appearance only toward the close of the former, so that here the faunas overlap as in northwestern Pennsylvania. It is possible that when the detailed revision of the Devonian column has been carried across from eastern New York by Prof. H. S. Williams into Ohio the beds of the Catskill will be found interlocking with beds of other tints, which in Ohio become the Bedford and Cleveland shales. If we bear in mind these facts:

"*First*, that the Chemung and Catskill deposits were laid down in a shallow basin subsiding most rapidly at the east and along a line rudely parallel to the Blue Ridge trend;

"*Secondly*, that the deposits would be much greater near the mainland at the east than at two hundred miles away; so that six hundred feet more or less of fine material in Ohio would more than fairly represent the four thousand feet of Chemung in eastern Pennsylvania; and

"*Thirdly*, that the water beyond the reach of the great land wash held a Chemung fauna throughout the whole time of the Catskill depost; there will be no serious difficulty in the way of accepting these suggestions.

"The conclusions to which I am led are:

"*First*, that the series from the beginning of the Portage to the end of the Catskill forms but one period, the Chemung, which should be divided into three epochs: the Portage, the Chemung, and the Catskill.

"*Secondly*, that the deposits of the Catskill epoch were not made in a closed sea or in fresh-water lakes.

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‡ C. L. Herrick: Bulletin Geological Society of America, Vol. II, p. 34 seq.

"*Thirdly*, that the disappearance of animal life over so great part of the area toward the close of the period was due to gradual extension of the conditions existing in southeastern New York as early, perhaps, as the Hamilton period.

"*Fourthly*, that the Chemung period should be retained in the Devonian."

CHAPTER LXXXXVI.

VIIIg, Chemung in N. Pennsylvania.

The Chemung formation of southern New York is the first in ascending series to cross the state line ; but nowhere in our northern counties (except Erie) is the country eroded deep enough to exhibit the lower parts of the formation.* It does not spread over northern Pennsylvania as it does over southern New York in a broad surface sheet ; but only in parallel ranges of lower hill country, separated by parallel ranges of higher mountain land, slanting from N. 60° to S. 60° W. The mountain ranges are strips of higher formations left lying upon the *Chemung*, burying it to various depths. Along the southern counties of New York we have a country consisting entirely of *Chemung* rocks, dipping gently southward into Pennsylvania, but slightly waved. Along the northern counties of Pennsylvania we have a country of *Catskill*, *Pocono*, *Mauch Chunk*, and *Pottsville* formations, capped on the very highest lands with patches of *Coal measures ;* and streaked with belts of *Chemung ;* as represented on the colored geological maps of Potter, Tioga, and Bradford counties ; Susquehanna county being mostly and Wayne county wholly *Catskill ;* the underlying *Chemung* being everywhere buried, but at no great depths. (See White's colored county maps.)

The broad streaks of *Chemung*, separating the still broader streaks of higher formations, are produced by parallel anticlinal waves of great length and regularity, with a general direction from east northeast to west southwest. The intermediate belts of higher rocks have been preserved in the alternate synclinal basins. The lowest rocks come to the surface along the central line of each Chemung

*In southern Bradford, however, along Towanda creek, on Gulf run a deep section is exposed (see further on).

belt; patches of the highest strata, the Carboniferous, remain on the mountain tops along the central lines of the basins. The drainage of the country does not obey the strike system; the main streams do not flow along the belts of low land between the belts of high land, either in a direction east northeast or in a direction west southwest; they cut across the belts; make crooked gorges or cañons through the high lands, and deep trenches in the low lands; and in these trench-like transverse valleys the uppermost *Chemung* strata exhibit themselves.

Potter county is crossed by six anticlinal axes, bringing up the *Chemung* to the surface more or less according to the heights of the arches. (See Sherwood's colored map.)

In the northwest corner of the county the broad anticlinal valley of Sharon township, the northern half of Oswayo, heads up southwestward in McKean county, and broadens northeastward into the general *Chemung* country of New York.*

South of the Sharon anticlinal runs the Oswayo synclinal mountain range, from the forks of the Genesee at Perryville to Williston on the McKean county line.

The Roulet-Hebron-Bingham anticlinal valley next south, is filled with *Catskill* strata, through which the upper beds of the *Chemung* show in the water courses of the Genesee at Bingham and Ellisburg; at Rose lake; at East Hebron; on the Oswayo creek; and all along Fishing creek from Hebron to Roulet.

South of this runs the Coudersport synclinal mountain from Bingham Centre to Forest House on the McKean line.

The Homer-Ulysses-Catskill anticlinal valley, next south,

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* It must be held in view that the anticlinal waves sink very slowly southwestward; so that all the Chemung belts—in other words, all the southwestward pointing prongs of the Chemung country of southern New York—terminate at various distances south of the state line; the valleys which they produce heading up southwestward; the top rocks of the Chemung sinking into a sort of a circus or cove where the intervening bounding mountain belts of the upper formation meet and spread out westward as a continuous whole. Where the valleys are produced by exceedingly gentle arches, the Catskill formation forms the general rolling floor of the valley, and the Chemung rocks are seen only where this general floor is cut down to a still greater depth in the beds of the streams.

is too shallow to show the top of the *Chemung*, except at Louisville, and in the various head valleys of Cowanesque creek, in the northeast corner of the county.

The Chatham-Farmingham anticlinal rises rapidly northeastward at West Pike postoffice, on Pine creek, producing the *Chemung* valley of Sunderlinville, Sabinsville, Little Marsh and Farmington Centre in Tioga county, growing wider and spreading across the Tioga river into New York; covering the whole northern border of Tioga county with Chemung rocks, between the Cowanesque mountain on the north (projecting into New York) and the Tioga mountain on the south.

The next synclical mountain range to the south in Potter county, is that of Mill Creek, in Potter county, extended eastward as the Tioga mountain. The New Bergen anticlinal valley runs quite across the county, with a floor of *Catskill*, except in the beds of its numerous water courses, where the top of the *Chemung* generally appears along the central line of the valley. The *Chemung* formation here disappears, descending southward not to rise again to the surface until we reach its Susquehanna river outcrops back of Williamsport.

In Tioga county, the Wellsborough anticlinal makes a wide belt of *Chemung* from Pine Creek east northeastward into Bradford county, between the Tioga mountain on the north and the Blossburg mountain on the south. The centre line or axis of the arch crosses Marsh creek in the neighborhood of Wellsborough, and Tioga River between Mansfield and Canoe Camp. The Tioga mountain range ends (eastward) at the Bradford county line; and the two *Chemung* belts (the Farmington belt north of it and the Wellsborough-Mansfield belt south of it) uniting around its end, cover all the northern townships of Bradford.

The Towanda anticlinal cuts across the southeast corner of Tioga county, between the Blossburg mountain on the north, and the west prolongation of the Towanda mountain on the south. In this deep valley the *Chemung* makes a surface belt about three miles wide; crossing the Northern Central railroad at Canton; and passing on north of Towanda creek, to and beyond the Susquehanna river into Susquehanna county. This *Chemung* belt is separated from the Wellsborough belt of *Chemung*, north of it, by a broad synclinal belt of *Catskill* rolling hill country.

The Towanda mountain (synclinal) of southern Bradford ends before reaching the Susquehanna river; east of which it is continued into Susquehanna county by a belt of *Catskill* rolling hill country.

South of the Towanda mountain and between it and the Sullivan county plateau with its Bernice coal basin, lies a broad low country of *Chemung*, produced by the Wilmot anticlinal, and spreading over the northwest corner of Wyoming into the southwest corner of Susquehanna; also, extending west into Sullivan county as far as Eldredville.

In Sullivan county no other *Chemung* outcrops appear.

In Susquehanna county, the whole surface is occupied by *Catskill* rocks, except in the deep head valleys of Wyalusing creek in Rush township; in the deep valleys of Choconut and Apolacon creeks in the northwest corner of the county; in the deep valley of Snake creek, from Upsonville to the State line; and in the cliffs and ravines of the Great Bend of the Susquehanna.* The upland is all *Catskill*.

In Wayne county no *Chemung* outcrops are recognized by Prof. White even in the deepest valleys. The Catskill mountain plateau through which the Delaware river flows for 45 miles, along the eastern border of Wayne and Pike counties, extends nearly to the Hudson river along its northern slope. The southern limit of the *Chemung* (sinking southward under it) runs from the Great Bend of the Susquehanna river northeastward towards Albany; encircles the mountain; descends the Hudson valley; and returns

* This statement is based upon Prof. White's adoption of a special division plane between *Catskill* and *Chemung*, in his reports G5 and G7. Instead of topping the Chemung with the *Fall Creek conglomerate* (*Cascade Sandstone, Third oil sand*) he fixes its upper limit at the highest strata which hold Chemung shells, two or three hundred feet lower than the conglomerate. Mr. Sherwood calls the intervening rocks *transition measures*. But as these transition measures crop out in the steep hillsides of the deep valleys mentioned above, the geographical outspread of Chemung surface is scarcely changed in Susquehanna county; but would be greatly changed on the map of Bradford county.

southwestward to the Delaware ten miles above Port Jervis.

It is impossible to give a section of the *whole Chemung formation* in any of the northern counties of our state. The best we have has been constructed with infinite pains by Mr. Lilley, at Le Roy, on Towanda creek, in Bradford county. Here at least 700 feet of Chemung rocks have been studied and their fossils collected and compared with those of the New York outcrops. (See Proceedings of the American Philosophical Society.)

Elsewhere in the northern counties only partial sections have been got, none of which have been instrumentally measured; but the formation contains some remarkable conglomerates, limestones, and iron ores, with belts of red shale, the outcrops of which have been observed at various localities, although not persistently traced across the country. One of these conglomerates is of the greatest geological importance, as there is very little doubt that it represents the Third and lowest oil sand of Venango county; and, therefore, in speaking of the Chemung formation in northern Pennsylvania, it must be understood to include the *Venango formation* as its uppermost subdivision. The same conglomerate is recognized throughout all middle Pennsylvania and, therefore, in this respect also has the highest value.

The *Mansfield iron ore beds* furnish another marked horizon in the *Chemung formation*, in Tioga and Bradford counties. When the formation, sinking southward beneath the Allegheny plateau of Lycoming county, rises again to the surface at the southern foot of the Alleghenies, north of Williamsport, the same iron ore beds come up with it. But in the middle counties of the state, they are not plainly indicated.

The *Burlington limestone* of Bradford county is not so certainly a fixed horizon in the *Chemung formation*. In middle Pennsylvania beds of fossil shells are too numerous to allow of any one of them being identified with it in the present state of our knowledge.*

* The Chemung formation along the New York state line must be studied

We will now examine a number of local sections in the northern counties where the upper Chemung rocks appear along the deeper water courses.

VIII g. Chemung in Susquehanna county.

The most easterly exposure, and a very satisfactory one, is obtained at the falls of Cascade creek in Harmony township, Susquehanna county, a mile from the New York state

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in connection with the New York outcrops; the outcrops of the Chemung rocks in middle Pennsylvania must be studied by themselves. No one general section can be offered as a guide to the field worker in any county of the state. In each county the *Chemung outcrop* will make some different exhibition of itself, and the student must take its local sections, imperfect as they are, for his guide. We have seen how difficult it is to subdivide the Chemung in New York; how it changes its character in passing from middle to western New York; what doubt is thrown upon the once used Ithaca subdivision; how difficult it would be to carry White's *Girard shale* eastward through Hall's into Vanuxem's fields; and what uncertainty is still felt whether or not the Venango oil rocks should be considered the uppermost subdivision of the Chemung. These and other embarrassments will be encountered by the student of the Chemung, in all the counties of the state where it comes to the present surface.

It has always been taken for granted that the palæozoic sediments in Pennsylvania were very much thicker than in New York, and that a decided thinning of each formation could be either observed, or taken for granted in proceeding from the south northward. This is undoubtedly true for the older and lower great formations from No. I to No. V; but it is of doubtful validity in the middle Devonian No. VIII system. Measurements across the outcrop in middle Pennsylvania are easy, the rocks being turned up at various angles and sometimes vertical. In New York they lie nearly horizontal; the dip being exceedingly hard to measure, or even to estimate; while broad and gentle anticlinal waves produce large uncertainties for any calculation. It can hardly be said however that the Portage and Chemung formations, taken together, are as much thinner in middle New York than in Middle Pennsylvania as we might expect. They seem to measure in middle New York about 2500′: and about the same in Huntingdon county, Pa. But there is the greatest uncertainty in fixing the upper limit of the Chemung both in New York and in Pennsylvania. In fact, there is no criterion for the correctness of any proposed plane of division between the top of the Chemung and the bottom of the Catskill. The assistant geologists of the Pennsylvania Survey differ in estimating the thickness of the Chemung; Prof. Stevenson giving it 3500′ in Bedford and Fulton counties, and Prof. White 2500′ in Huntingdon. But this is because the upper 1000′ of Chemung in Bedford, is made to be in Huntingdon county the lowest 1000′ of the Catskill. It is merely a matter of names, not in any wise affecting the sectional description of the strata. In Huntingdon county, the Allegrippus conglomerate is made the top of the Chemung. In Bedford and Fulton a *conglomerate* a thousand feet higher is made the top of the Chemung. The two conglomerates can both be traced continuously from Huntingdon into line and five miles west of the Wayne county line (G5, 73 and 98). Here the Erie railroad crosses the deep and narrow cañon, in the sides of which are seen the strata at the bottom of the following section. The upper rocks are exposed on Starrucca creek from Harmony Centre down to the Susquehanna at Lanesboro'.

Starrucca Creek and Cascade Section.

New Milford lower sandstone,*	25′
Concealed,	65′
Sandstone,	5′
Shales, gray,	5′
Sandstone, gray,	4′

Bedford, and can nowhere be mistaken for each, each keeping its place and distance from the other. It is a matter of personal preference whether the thousand feet of rocks between the two conglomerates shall be called Catskill or Chemung. Whether these two conglomerates represent the first and third Venango oil sands, is a question of fact and not of names. If they do, their distance of a thousand feet apart on the Juniata becomes of geological importance, in view of the fact that the first and third Venango oil sands are only 300′ apart.

Prof. Stevenson's mature views of this subject have been given in his own words in the last chapter.

* The New Milford lower sandstone at the top of the section juts out from the cliff on the left bank of the Susquehanna, just opposite the junction of the Jefferson branch with the main line of the Erie railroad, two miles from Susquehanna Depot, at 1300′ A. T. The same rock is seen three and one-half miles down the river in Oakland township, at 1250′ A. T.; its base 300′ above the red shale on the railroad track beneath it. Ascending Starrucca creek eastward, this sandstone at Stevens' Point is only 1075′ A. T. It has been extensively quarried just below Stevens' Point for bridge piers; a very hard, bluish-green stone, through which are scattered small fragments of olive shale.—The interval under it should hold a good deal of red shale.—The sandstones next below are seen at the Narrows where the creek has cut a new cañon; its old channel having been gorged with Drift; the thirty foot sandstone has also been somewhat quarried; a dark olive stone not current bedded like the other sandstones above.—The 125′ shales, with Chemung shells near the base, might be taken as the top of the Chemung formation and the bottom of the Catskill.—The little quartz conglomerate, also in the olive sandstone, has flat pebbles.—The iron ore farther down is worthless, but represents geologically one of the Mansfield iron ore beds of Tioga county; and the brick red shale next below, which can be seen all along from Susquehanna Depot to Jefferson Junction, is one of the Mansfield red beds. It often appears in the railroad cuttings as it rises northward towards Cascade creek just about as fast as railroad grade; so that at the Cascade creek bridge it is 220′ above grade at Susquehanna Depot; the rise from Lanesboro' being 150′ in two and one-half miles, northward.—In the fifteen foot olive shale (3′ above the bottom) is a rock made up of shells, fragments of

Shales, sandy, gray,	6′
Sandstone somewhat massive,	30′
Shales, olive, with Chemung shells near the base,	125′
Sandstone, olive (quartz conglomerate 1′ near middle),	8′
Shale, olive,	8′
Sandstone, olive,	4
Shale, olive (iron ore bed near middle),	40′
Shale, brick red,	10′
Sandstone, green, shaly,	6′
Shale, red, soft, greenish at top,	20′
Shale, olive, fossiliferous,	15′
Sandstone, massive, yellowish-white (Fall creek conglomerate),	25′
Shale and sandstone, olive, fossiliferous,	30′
Sandstone, brownish (prismatic fracture),	25′
Shale, bluish-olive,	25′
Sandstone, brownish, very fossiliferous,	15′
Shales and flags, all very fossiliferous,	25′

From the New Milford lower sandstone at the top of the section down to the Fall creek conglomerate is 350′. Prof. White traced these rocks westward down the Susquehanna and along the New York state line to Fall creek in Bradford county (where Mr. Sherwood gave the name to the conglomerate), and found the interval to be there 325′, There can be no doubt about the identity of the Cascade creek sandstone and the Fall creek conglomerate. The special interest attaching to the latter is Prof. White's theory that it is identical with the Panama conglomerate of western New York and the third Venango oil sand.*

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fish bones, and pebbles of shale and sandstone cemented together by lime and silica, probably one of the Bradford and Tioga county Chemung fish beds.—The Fall creek conglomerate is here a massive yellowish-white sandstone of coarse grain, full of carbonized limbs and branches of a land vegetation, in fragments so injured as not to be referred to any kind of plant. The lower layers of the rock are crowded with Spirifers, Rhynchonellas, etc., all of Chemung type. The rocks contain also a considerable quantity of iron pyrites.—The brownish, prismatic sandstone, thirty feet lower down, is full of Chemung shells and crinoidal fragments; its layers, one or two feet thick, breaking into regular blocks, between joints very even and close together. The underlying shales and sandstones to the bottom of the section are rich in species of Spirifera, Rhynchonella, Leiorhynchus, Productella and other genera, with multitudes of small crinoidal stems. This is the lowest stratum of the Chemung formation which appears anywhere in Susquehanna county.

* Mr. Sherwood claimed to have traced the *Panama conglomerate* eastward all along the state line to his Fall creek exposure in Bradford county, but Prof. White relied independently on the characters and relative positions of

Two miles above *Great Bend Depot*, the river flows through a gorge only 100 yards wide between vertical walls of horizontal strata, in which are seen flaggy sandstone, 30′; shales, 12′; sandstone, 6′; blue shale, 6′; flaggy sandstone at river level visible 3′. In the middle of the 30′ flaggy sandstone lies a bed of shale 5′ thick, with many iron balls. The underlying shales contain similar iron balls. The 6′ sandstone is called locally the Red Rock, because on its boldly jutting edge the Indians have painted figures in red (G5, 92).—The *Great Bend limestone* is here 30′ above the water, and can be traced in the cutting of the railroad nearly to Great Bend. A flagstone quarry, used for side-walks, seems to occupy the place of the limestone one mile below Red Rock. The Chemung rocks which line the valley of the Susquehanna Great Bend contain considerable quantities of binoxide of manganese; bogs of wad being deposited at the outcrops, several tons of which were once mined near Great Bend (G5, 94). Just below Susquehanna Depot, the probable Mansfield iron ore horizon is represented by 10′ of very red shale; and many iron balls have here fallen from the strata above. A quarter of a mile above the Depot are seen outcrops of sandstone massive, 10′; shales, 4′; olive sandy shales, 8′; reddish shales, with many kidney-

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the two rocks with their similarly associated fossils, for his confirmation of the original statement.—The Catskill rocks are carried down by Prof. White nearly 200′ below the New Milford lower sandstone, the highest level in the series where Chemung shells are noticed in this district. Of course this is to a certain extent an empirical division plane between Catskill and Chemung. The cliffs between which the Susquehanna makes its Great Bend into Pennsylvania are nearly 450′ high. The country inside and outside of the Great Bend is, therefore, covered with the lower strata of the Catskill formation; the New Milford lower sandstone making a well-marked horizon, jutting out near Great Bend depot in a bold promontory, affording a magnificent view of the valley, and named by the inhabitants, Fort '76, 405′ above depot level (1314′ A. T.).—Following this New Milford lower sandstone cliff down the river, and measuring from it 400′ downwards, appears what Prof. White calls the *Great Bend limestone*, a local deposit from six inches to 24″ thick, sometimes vanishing, 20′ above the river level at Lusk's, containing Streptorhynchus chemungensis, Spirifera disjuncta, Rhynchonella contracta, Leiorhynchus newberryi, and many other common Chemung shells. It seems to lie uncomformably in some places on finely laminated shales; beneath which, again, lie sandy layers with iron ore balls from 1″ to 18″ in diameter.

shaped nodules of iron ore (Mansfield ?), 10′; flaggy sandstones to railroad track, fossiliferous, 10′; the whole series being the upper beds of the Chemung. The flaggy sandstone, holding many specimens of Rhynchonella contracta, is probably the fossiliferous bed in the Red Rock section. In Liberty township the Chemung top strata are cut into by Snake creek from Franklin down to the state line to a depth of perhaps 200′; the uppermost recognizable Chemung layer lying about 100′ below the New Milford red shale, here 115′ thick under New Milford lower sandstone, or Fall creek conglomerate. In Silver Lake township, the Chemung is cut into only at Brackney. In Choconut township, Choconut creek cuts into the Chemung about from 100′ to 200′, but the outcrops are concealed under drift. In Apolacon township, about 400′ of Chemung are cut through by the Apolacon valley, but covered with a deep coating of drift. The Fall creek conglomerate shows just over the New York state line, a mile and a half from the Bradford county corner; and here the axis of the broad gentle Blossburg anticlinal passes, lifting the Chemung to a somewhat higher elevation than at the Great Bend of the Susquehanna.

VIII g. Chemung in Bradford county.

The Towanda anticlinal crosses from Lycoming into Tioga county at Henslertown, and runs east north-east to East Canton on Towanda creek, and so on to Towanda on the Susquehanna. It brings up the top of the Chemung at Henslertown and makes a belt of Chemung at the surface, about two miles wide, south of Ogdensburg and Union Centre. Along Towanda creek, at Leroy, West Franklin, Franklindale, and Monroeton, the south dip from the anticlinal of the Chemung rocks is very steep. The creek runs at the top of the Chemung, the Catskill above it forming the north flank of the mountain. The south dip ranges from 25° to 45°. The north dip is always much gentler and can be well seen at Cedar Ledge, two miles south of Canton, and along the railroad near the village. Also all along Sugar creek for fifteen miles from Troy to North Towanda at the river. But the finest exposures of north dip are on the Susquehanna, opposite and a little above Towanda, and at the Red Rocks below Wysauking. Fine exposures occur along Roaring run and Towanda creek, making high and conspicuous cliffs. The upper Chemung strata are finely displayed in Union township, Tioga county, a mile west of Green's sawmill, and along the Lycoming valley, from Roaring Branch to Corner Stone; at Cedar Ledge, and again two miles north of Granville railroad summit. The two best exposures are on Gulf brook at LeRoy, Granville township, and at the narrows, a mile below Franklindale, in Franklin township. The cliffs opposite Towanda and at the narrows below Wysauking afford good sections. (Here occurs the slip fault figured in G, page 39. Note.)

The Wysox fault is shown where the township line of Standing Stone comes to the river and the cliffs bend sharply around to the south. Here gray and bluish shale and sandstones rise from the railroad northward at an angle of about 20° to go over the Towanda anticlinal axis at the northern end of the cliff. The fault rises from the railroad to the hilltops northward at an angle of about 30°. The rocks south of the fault have slid upon it upward, crushing a space of from 15′ to 30′, turning up the edges on the one side, and down on the other, grinding them to fragments, while the unbroken edges on both sides of the fault are polished as smooth as glass and brushed round by friction. The fault probably extends to Rummerfiield creek, four miles to the east; being indicated by a disturbance between the two saw-mills a mile and a half up the creek. If it be the same fault; its course must be nearly due east and west.

Along Towanda creek the Chemung rocks are many hundred feet in thickness, consisting of gray shale and sandstone, sometimes bluish, greenish, or olive, or occasional layers charged with lime. East of the Susquehanna, the upper beds alone reach the surface and represent that transition series, Catskill-Chemung, in which red shale and sandstone are abundant, the sand of a coarser texture, the strata more false bedded, and the fossil shells less numerous and not so well preserved. We evidently rise in the series of Chemung strata going east across the Susquehanna toward Susquehanna county. The calcareous beds of the transition strata are found both east and west of the river, but seem to be more heavily charged with shells westward.

In Canton township, the high hills south of the village are Catskill, confining the Chemung to the bed of the valley. The Chemung surface opens broadly northeastward and covers Granville and northern LeRoy, southeastern Troy, southern West Burlington, most of Burlington, and all of north and south Towanda.

The *Wilmot anticlinal* crosses the Susquehanna North Branch near the Wyoming county corner, bearing east northeast through Tuscarora township into Susquehanna county ; and west southwest past Wilmot and Laddsburg into Sullivan county ; crossing the Wilmot-Albany township line a mile north of the county line.

Its southern dips toward Bernice are stronger than its northern dips toward Towanda. Good exposures of Chemung are scarse in the broad valley made by the anticlinal. The rocks exposed along the river from the Wyalusing downward are the upper strata of the Chemung and overlying strata, which may be called a transition series of Chemung-Catskill ; gray sandstones and shales interstratified with red shales and sandstone ; the prevailing color gray ; but near the mouth of Sugar Run more or less red rocks, being more abundant down the river ; the best exposures are along the river and on Sugar Run, Tuscarora and Little Tuscarora creeks. A few flagstone quarries have been opened, one of considerable extent at Bowers, on Little Tuscarora, furnishing good building and flagging stone ; dipping southward.

The Catskill and Chemung formations cannot be distinguished in this district, the character of the rocks being no guide, and Chemung fossils being found many hundred feet higher than what would be considered the top of the Catskill formation if only the gray color and flaggy constitution of the strata were taken as indexes. All that we can say is that we have here, lifted to the surface by the

Wilmot anticlinal, the upper measures of the Chemung; but the texture of the stone is coarser and there is less calcareous matter; more sandstone and less shale; more red shale and less greenish-gray than in the typical Chemung country on the State line. Moreover, there are fewer species of shells, and fewer individuals to the species. We nowhere see those myriads of fossil shells which people the rock deposits of the Chemung sea along the State line. But we find thin, gray calcareous beds at intervals in the series containing considerable numbers of the same species of shells which occur so much more abundantly farther north; for instance, Gramysia elliptica, Rhynchonella contracta, Streptorhynchus pandora, Athyria angelica, and two or three species of Productus. These species can be collected from a gray rock three-quarters of a mile up Sugar run. Also from a limy rock on the river opposite Browntown, below the mouth of Sugar run. Also from fallen masses of a lime rock on the west bank of the river at Kinney's Ferry. But the best place to study the beds and their fossils is on the mountain road ascending from and a little east of Skinner's Eddy, near the Wyoming county line.

Skinner's Eddy Section.

Sandstone, gray, top of hill, ...	5′ to 10′
Reddish shale, thin sandstones, ...	5′ to 10′
Gray shale and sandstone with broken plants and Chemung shells, ...	122′
Red and gray alternations (one thin fish bed), ...	208′
Concealed to foot of hill, ...	200′

The shells are not abundant, but include *Rhynchonella contracta* and *Spirifera mesacostalis*, with other species. The fragments of fish plates are probably *Holoptychius*. The relics of plant vegetation are here a hundred times more abundant than in the Chemung districts to the north; carbonized stems of reed-like plants being very common, and in some places beds one or two foot thick being largely composed of them.*

* This exhibition of floating plant remains at so early a date in the palæozoic ages, far older than the first coal beds of the Pocono formation number ten, is very interesting. Most of the impressions appear to be those of water plants, or plants growing in shallow water along the margin of bays

The Burlington limestone.

This is one of the most remarkable of the Chemung strata in Bradford county; a nearly solid mass of sea shells 40′ thick; the shells crowding the rock by millions; an accumulation requiring a long period of time; going on without any deposit of shale or sand, for no partings are visible; quarried by Cline, Morley and Campbell, a mile east of Burlington, on Sugar creek; making a gray, strong lime for farm use.*

This limestone may be more than 40′ thick, and evidently has a wide distribution in Bradford county, as it has been detected outcropping at several places east of the Susquehanna river. For instance, a mile and a quarter northwest from Herrick township, bands of lime rock show at Carr's house, dipping north, containing fossil shells. And again, a mile southwest from Herrick, at the forks of the road, containing more lime. And again in Pike township, four miles south southwest from Le Roysville, at a school house, dipping north over ten feet of red shale. And again two miles below LeRoysville, near Coggswell's (G, 41).

It is not absolutely certain that such limestone beds persist for considerable distances and can be identified as the same beds at different places, because they are not of the nature of ordinary limestone strata, but have been produced by local accumulations of shells, either living in banks or colonies, or accumulated after their death by currents in hollows of the sea bottom; and this process might take place at any time in the Chemung age or at any stage of the Chemung deposits. They cannot, therefore, be used with confidence as key rocks from which to measure upward or downward, as, for instance, the persistent limestones of the

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and rivers; but with these are mixed pieces of ferns, tree ferns, etc., and true land vegetation broken and ground up by water currents before being floated into and deposited at the bottom of the sea. This ground-up, decayed wood, embedded in sand, is usually carbonized or converted into coaly matter (G, 22).

* Analysis of McCreath:—Lime 41.0; carbonic acid, 33.2; sesquioxide of iron, 4.4; alumina, 2.6; magnesia, 1.1; sulphuric acid, 0.167; phosphoric acid, 0.279; insoluble residue, 18.0.

coal measures are used by well-borers seeking the oil sand-rocks at supposed depths.—On Towanda creek, two miles south of Canton Corners, where the Mansfield ore beds were opened as long ago as 1841, the upper ore bed 2′ thick is overlaid by 10′ of lime shales, which are so full of shells as to be almost a limestone. The ore bed 2′ thick is here itself very fossiliferous, containing Atrypa punctata, Spirifera mucronata, Cypricardites, Encrinal stems, etc. (G, 41, from Geol. Penn. 1858).—This limestone was considered by the first survey as lying 50′ beneath the top of the Chemung. In a future description of the Mansfield iron ore beds, it will be seen that the second ore bed on Wilson's land, on Mann's creek, near the Tioga river, has above it, near the top of the hill, a bed of limestone or calcareous rock said to be 6′ thick, largely composed of sea shells, which evidently did not live at the place where they now lie, for they are all ground up and broken to fragments by the action of waves. They are so abundant as to make up nearly the whole mass of rock; which burns into good lime and has been successfully used as flux in the Mansfield iron furnace.*

Gulf brook section, Leroy, Bradford Co.

Mr. A. T. Lilley of Leroy published in the Amer. Philos. Soc. Proceedings, Jan. 15, 1886, at my request, the results of a long continued series of searches into the fossil contents of a remarkable fine exposure of Chemung strata near his residence. It is the best section of the formation that we have in Pennsylvania. One slab pictured on plate, page —, will sufficiently show the vast abundance of mollusca inhabiting the waters of that period. The section is as follows :—

* This limestone was described by R. C. Taylor in his old Memoir on the Blossburg coal fields. McCreath's analysis shows lime, 29; carbonic acid, 23; insoluble, 42, etc.

What seems to be the Burlington limestone crops out on the Susquehanna river hills, near Wyalusing. Along the main road, on the east side of the Wyalusing, a mile and a quarter above the village, and again, two miles and a half above the village, the fields are strewn with large, detached masses of limestone resembling in all respects, the Burlington (G, 27).

The limestone mentioned in the description of the Great Bend of the Susquehanna may be perhaps also identified with the Burlington limestone of Bradford county.

Shale, light colored, with *Atrypa* and many other unrecognizable shells (a *Spirorbis*, and *Rhynchonella*),		1
Sandstone, gray, holding a *Produetella bed*,		10′
Shale, green,	15′	64
red,	4′	
green,	20′	
gray, holding a *Grammysia elliptica* bed,	25′	
Iron ore bed, holding *Spirifera, Pterinea, Grammysia, Spirorbis, crinoids, fish* fragments,		4
Shale, green,	20′	28′
red, with *seaweeds (fugoids)*,	8′	
Sandstone, green		20′
Shale and sandstone, red, with unrecognizable fossils,		4′
Lime-conglomerate, holding *Spirifera, Productella, fish*,		6′
Shale, green,	10′	52′
pink,	2′	
green,	40′	
Sandstone, green,	2′	22′
green,	19′	
gray,	1′	
Shale, green,		52′
Strophomena bed,		1′
Sandstone, green,		14′
Shale, green,		40′
Sandstone, brown, with *Spirifera* and *Productella*,	1′	9′
gray, with *Crinoids* and *plant remains*,	8′	
Shale, green,		6′
Sandstone and shale, green, with *Spirifera* and crinoids,	8′	121′
gray,	60′	
green, with *fossil shells* and *fish* (*Bothriolepis*)	53′	
Shale and sandstone, red, with *Spirifera, Rhynchonella, Spirorbis, fish* (*Bothriolepis*) and *plants* (*ferns*).		14′
Sandstone, brown, with *fossil shells* and *fish* (*Holsphlychins*),		39′
Shale, green,		6′
Sandstone, red, with *iron ore*, and *fossil shells*,		8′
Shale, gray,		8′
Sandstone, with *Lime-iron-ore*, and *crinoids*,		12′
Shale, brown,		20′
Sandstone, with *red lime-iron-ore; fish* (*Bothriolopis*),		11′
Sandstone and shale, gray; *fossil shells; carbonized plant stems*, and *iron* and *copper pyrites*,		2
Sandstone, brown, with *Cryptonella*	10′	45
brownish, with *Cryptonella* and *spirorbis*,	35′	
Limestone bed, crinoidal,		4′
Shale bluish,		8′
Sandstone, *limy*, red,	9′	39′
brown,	18′	
green, with *fish* (*Pterichthys rugosum*),	8′	
limy,	4′	
Sandstone and shale, green,	90′	225′
Sandstone, *limy*,	51′	
Sandstone and shale,	130	

Shale, gray,	63′	78′
Conglomerate with *fossil shells*,	3′	
Shale, green,	12′	
Sandstone and shale, green		270′
Limestone with *fossil shells*,		2′
Sandstone and Shale, with *Grammysia circularis* and a coral *Zapprentis*),		220′
Sandstone, gray, with *seaweeds (fucoids)*,		1′
Sandstone, green, with seaweed (*Dictyophytum*),		42′
Blackish shale, with plants (*Lipidodendra; Sigillaria*),		50′
Sandstone and shale, green and brown,		100′
Shale, green,		25′
Ambocœlia bed, with *Loxomena, Spirifera, grammysia; Bellerophon*,		2′
Concealed gap of		70′
Ambocœlia bed, in green shale of		50′
Concealed gap of		50′
Shales green and olive, holding *Orthis, Chonetes, Rhynchonella, Cypricardites, Tentaculites, Pterinea*, and a shale like *Trigonea*,*		150′
Concealed gap of		183′
Shale and sandstone, bluish,		13′
		2201′

In this Gulf Brook section it is easy to see four groups of strata :—

1. At the top nearly 700′ of green and grey shales and sandstones, with *red* shales and brown sandstones, some limestone and limy layers, some iron ore beds (with copper pyrites at one place), vast numbers of *Chemung shells*, at least six horizons of *Catskill fish* remains, one *fucoidal* layer, one bed with *ferns*, one bed with *carbonized plant-stems*, and at least three horizons of *crinoidal* fragments.

The *fish beds*, and *red rocks* lie mostly between 450′ and 650′ down. This is the *Mansfield red group* proper ; but there are two *fish beds* and three *red beds* within 140′ of the top. No *fish*, no *red* rock, is seen in the 1500′ of strata beneath the lowest fish bed. Evidently the fish remains are to be sought for in connection with the red rocks. Fish characterize the *Catskill* formation in eastern New York ; nevertheless we know that they lived in earlier (*Chemung, Hamilton*, even *Clinton*) times ; and their absense from this local Gulf Brook section is no proof that isolated specimens will not be found hereafter at any horizon in the 1500′. The

* *Trigonia* is only known as a Mesozoic fossil.

fact remains however, that vast numbers of fish perished and were fossilized toward the close of the *Chemung* and beginning of the *Catskill* age; and that apparently throughout the whole extent of the Appalachean sea; so that there is a well fixed *fish horizon* in northern, middle and western Pennsylvania.

The *Mansfield iron ore beds* have something to do with this general destruction of the fish. The iron pyrites and especial the *copper* pyrites, in the 2′ bed of gray sandy shale, with numerous floating fragments of charred wood, 572′ down in the section, is suggestive. The red beds are made so by oxidized sulphate of iron poured at that time into the sea in great quantities, rendering it deadly to the fish; unless we prefer to think that the fish died of starvation, their proper food having been killed. This was at the beginning of the great *non-fossiliferous red Catskill age*, in which scarcely any shells can be found; no corals; no crustacea, but innumerable fragments of land plants floated into the sea; with a surplus of sand, and quantities of small pebbles; showing that the more peaceful waters of proceeding ages had become (in one region of the water basin at least) more turbulent. But the *Catskill formation*, so enormously thick in eastern New York and middle Pennsylvania, thins away to nothing on the Genesee, Allegheny, Conemaugh and Youghiogheny rivers; so that further west we see *Chemung* state of things containing nearly up to the base of the Coal Measures, and with *fish beds* on Lake Erie which may or may not represent these *fish beds* of our section.—The fish of our section belong to the Devonian genera *Bothriolepis*, *Holoptychius* and *Pterycthys*.—The shells which accompany them in the upper 700′ of the section are of the brachiopods *Atrypa*, *Rhynchonella*, *Spirifera*, *Productella*, *Cryptonella*, etc., the lamellibranchs *Grammysia* (*elliptica*) and Pterinea; the little spiral worm shell Spirorbis, etc.—Crinoidal beds occur at 75′, 320′, 325′ and 620′;—Fucoids at 100′;—and land plants at 320′, 460′, 572′.

2. *Green shales and sands* occupy the next underlying 800′; begining (at the top) with a limy sandstone just under

the lowest fish bed (664′); another limy sandstone at 760′; a *conglomerate with shells* (3′) at 958′; a *limestone with shells* (2′) at 1243′; a *fucoidal* sandstone (1′) at 1465′; under which are 40′ of green sandstone beds with the remarkable basket sea-weed (*Dictyophyton*)—*Grammysia circularis*, and a coral *Zaphrentis* are found in the lower part of this subdivision.

3. A notable *black shale formation*, with *coal plant fragments*, tree ferns and reeds (*Lepieodendra* and *Sigillaria*), comparable no doubt with the black slates of the Chemung in western New York. It is 50′ thick (1508′ to 1558′).

4. Green and olive shales extend downward to 2000; (for there can be little doubt that the gaps of 70′ and 50′ in the section conceal similar strata) and probably far down in the next 200′ (concealed) to the bottom of the section, where bluish shale and sandstone sets in (at 2188′).—The upper *Ambocœlia umbonata* (*gregaria*) bed (2′) at 1685′, contains *Spirifera;* the gasteropods *Loxonama* and *Bellerophon;* and a lamellibranch, *Grammysia.*—The lower *Ambocœlia* bed occurs in the 50′ of green shale (1755-1805) between the two concealed gaps in the column; so there this interesting little gregarous brachiopod probably made similar shell banks in this part of the section, beside the two exposed on Gulf creek. With it lived other brachiopods, *Orthis*, *Chonetes*, *Rhychonella;* the pteropod, *Tentaculites;* lamillebranchs, *Pterinea*, *Cypricardites* and the shell misnamed *Trigonia.**

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*The rocks under the *lower Ambocœlia bed*, dipping gently southward, are concealed to the south line of Granville township. At Granville Centre the rocks are geologically 250′ lower than at the line. In the interval the 150′ of shale with *Tentaculites*, etc., are exposed. Near Granville Centre, Adam Dennis' tannery bore hole is 96′ deep, and at its bottom lie the 13′ blue shale and sand. It is a pity that this bore hole could not be put down to find the top of the *Genesee black formation*, the *Tully limestone*, or some other well marked division plane, so as to give us the real dimension of the *Chemung* along Towanda creek.

CHAPTER LXXXXVII.

VIII–IX Fish beds.

It is certainly a remarkable fact that red rocks and fish remains so often go together. In the great Leroy (Gulf Brook) section there are no red rocks except at the fish horizons, and no fish beds except at the red rock horizons.*

Micaceous shales and sandstones are abundant in the upper Chemung and Catskill formations. It is unfortunate that so little attention has been given to their distribution

*This ought not to mean that fish *lived* in numbers only in the times of the red deposits; but contrariwise, it must mean that they *died* in great numbers at such times. There was an abundance of fish in the Chemung ages. It looks as if they were mostly destroyed at the opening of the *Catskill age.* Yet, the statement should be limited to such areas of the water basin as received in the Catskill age a large proportion of red mud and sand. Perhaps we should go one step further and say, a large proportion of mud and sand which subsequently, in later geological times, and perhaps gradually, lost their original gray color and became red, by iron peroxidation. The question arises, what was the chemical condition of the iron in the mud and sand when deposited? Was sulphate of iron the solution in sea water which destroyed the fish? And if so, did it issue from rivers draining volcanic or solfatara land regions? It is difficult to find evidence of a large solution of sulphate of iron in the sea water of that age. Calcareous beds are numerous: lime shales, lime conglomerates, lime-iron ore, and fossiliferous limestone, but no gypsum anywhere visible. The Mansfield iron-ore fish-bed has been frequently analysed, and only found to contain of *sulphur*, .026; .017; .035; .018; .150; .027; .018; .015; .018; .033; .059; .038; .014; .016; or in many cases merely a trace; whereas of *phosphorus* it has yielded .184; .229; .241; .298; .233; .311; .294; .258; .248; .185; .253; .603; .585; .903; .657; etc., most where fish are abundant, least where shells alone are seen in it. If carbonate of iron was the solution, we can understand that colonies of sea shells would appropriate the carbonic acid. Hydrated peroxide of iron would then be precipitated and form the cement of the mud-sand in which shells after death would be entombed. The abundance of fish remains may therefore merely indicate local abundance of fish food in the shape of shell colonies. As the red Catskill formation proper is almost devoid of fossil shells, absence of this food would account for the rarity of fossil fish in it,—that is, if our very imperfect knowledge of these barren red Catskill rocks does not deceive us into supposing such rarity.

through the columnar sections. Some of the better oil well records tell of a great number of micaceous layers.†

Fish beds in Susquehanna Co.

The New Milford fish beds of Susquehanna county, exposed in the railroad cuttings, 5 miles east of Montrose, are 48 miles E. N. E. of Leroy, and about 10 miles from the New York state line.—The *Gibson fish beds* of Susquehanna county, are exposed along Butter creek, 12 miles east by south of Montrose; and at Smiley on Tunkhannock creek 3 miles further E. S. E. From Smiley, Prof. White has traced them into Wayne county to Cherry ridge (south of Honesdale) 22 miles southeast of Smiley, or 75 miles (in a straight line) east of Leroy in Bradford county.—The New Milford and Gibson fish beds are placed by Prof. White in the Catskill formation, which occupies almost the whole surface of Wayne and Susquehanna counties, its

† There must have been a vast influx of fine mica flakes, the bouyancy of which is well known to carry them far and wide through an oceanic water basin. The decomposition of minute mica flakes reddens such azoic land surfaces as the Philadelphia mica-slate belt. If such decomposition takes place in sea water, it must redden sea bottom deposits. Perhaps a more thorough investigation of this problem would find a sufficient explanation of red rocks in the hydrated peroxide of iron set free from mica mechanically distributed through the old water basins and slowly settling into their bottom deposits. The apparent abundance of micaceous strata towards the close of the Chemung age certainly indicates some change in the land drainage of the time, by reason of which the rivers were able to obtain and carry down down to the sea far larger quantities of outcrop mica schist stuff than they had been doing in previous ages; and the minute size of the mica specks shows that the land from which they came was at a great distance. We ought to find out by laboratory experiments what effect sea water has upon floating mica; and whether the mica left in deposits may or may not be but the residunm of the whole influx of mica into the water basin, the rest being dissolved in transitu. The next question would then be, if mica be dissolved by sea water while floating, in what form is its iron set free, and in what form does its take its place as a constituent of the sea floor.

In this book I have set myself the task of asking questions rather than answering them, convinced that in this manner I can best arouse the attention and stimulate the rational curiosity of the people of Pennsylvania to the world (or rather worlds) of nature over which they have been used to walk and work like ants upon an iron chest thoughtless of its locked up contents. When a farmer's plough turns over a piece of sandstone which glitters in the sunshine and he asks himself whence came the little specks of mica in it, whether he gets an answer to the question or not, he has at least begun to study the geology of the planet on which he rides through space.

stratification being exceedingly flat, nearly horizontal. But they lie at various horizons in the formation; and these horizons seem to be several hundred feet above the horizon of the Mansfield (ore) fish bed of Tioga county (in the underlying *Chemung formation*, which only appears in the deep valley of the Susquehanna river at the state line).—Their depth beneath No. XII can be got with some approximation to the truth in the Cherry ridge (Honesdale) country by reference to the outcrop of the Pottsville conglomerate (No. XII) in Moosic mountain (overlooking Carbondale) 10 miles west of Cherry ridge; but it would not be safe to assume that the same beds at Gibson and Smiley lay at the same depth beneath No. XII; for, the thickness of the formations undoubtedly diminishes northwestward; and the whole of middle Susquehanna county has had all the upper formations cleaned off from the present surface. There are no deep synclinals (as in Bradford and Tioga Cos.) holding belts of Pocono mountain land, capped with No. XII and coal measures. *Sugarloaf peak* and *Ararat mountain* on the Wayne-Susquehanna county line (6 miles east of Smiley) rise indeed to 2450′ and 2600′ A. T.; but there are only 200′ or 300′ of *Pocono sandstone* (No. X) at the top of Ararat (see Report G5, p. 159).

A general section, however, will give some idea of where the *fish horizons* lie in the Catskill formation, vague as this term is, and changeable as we must regard it in all districts; keeping in mind the dangerful utility of all generalized sections even when constructed with the utmost conscientiousness, as this one certainly was. (See White's Report G5, pp. 55, 56, 58, 59).

XII.	*Pottsville conglomerate* (base),*		9′
XI.	*Mauch Chunk*, { red shale, 10′; dark shale, 5′ }	at	15′
X.	*Sub-Olean (?) conglomerate*,	40′	
	Shales, sandy, buff, etc.,	200′	
	Sandstone, massive, whitish,	125′	
	Shales (with sandstones) grey,	265′	

* It is possible that the sandstones overlying this red shale may be properly included in XI, making it 170′ thick. If so the heights of XII above the fish beds must be increased by 155′.

	Griswold's gap conglomerate,	35′= 665′
	Rix's Gap fish bed, near base,	at 680′
	Sandstone, current bedded, gray, etc.,	150′
	The same, with reddish sand-shales,	200′
	Mount Pleasant conglomerate,	25′=365′*
	Mt. Pleasant fish bed at its base,	at 1055′
IX.	*Mt. Pleasant red shale*,	150′
	Elk mountain shales and sandstones,	150
	Cherry ridge conglomerate,	20
	" " gray shales,	20′
	" " sandstone,	15′
	" " *limestone* and *fish*,	5′at 1410′
	" " *red shale*,	110′
	Honesdale sandstone, white,	25′
	" " *red*,	40′
	" " *gray*,	25′
	Montrose red shale (fish plate),†	180′at 1645
	Paupack sandstone,	25′
	" shales, *red*; green; sandstone,	200′
	New Milford upper sandstone,	40′
	" " middle sandstone,	300′
	" " lower sandstone (*fish*),	20′ at 2360′
	" " *red* and olive shale,	100′
	Starucca gray and olive shales and gray and olive sandstones,	500′ at 2585′

Fish beds in Bradford Co.

In Bradford county the key to the Chemung fish beds has been obtained by Mr. Lilley of LeRoy, on Towanda creek, in his admirable Gulf Brook section, given elsewhere, embracing 2000′ of Upper Chemung strata; the top of the section, at the creek, being a shale (with Chemung fossil shells) dipping south into the base of the Towanda mountian, here 1100′ high and capped with Olean conglomerate (base of XII).

The top of the Gulf Brook (Leroy) section must be at least 1500′ (and may be two or three hundred more) beneath No. XII.‡ As this agrees with the approximate depth of *Red Rock fish bed* beneath No. XII at Blossburg (1710′) I add 1700′ to all the figures of the section and get the following table:

* This 365′ can be placed in *Pocono X*, or in *Catskill IX*.

† A large fish plate seen in place 30′ beneath the Honesdale lower sandstone, near Honesdale, G6, p. 188.

‡ Top of mountain about 2100′ A. T. Dip at the base 30°± growing less and less to horizontal. From base to summit, half a mile. Lower half IX; upper half, X, IX, XII.

Leroy or Gulf Brook section.

	Top of section *beneath No. XII*,	1700′
a.	*Iron ore bed* (4′) holding *shells, crinoids, fish*,	1779′
b.	*Lime conglomerate* (6) holding *shells* and *fish*,	1837′
	(*Interval of gray and green fossiliferous shales, 279′.*)	
c.	*Green sandstone* beds (53′) with *shells* and *fish*,	2100′
d.	*Red shale and sandstone* (14) with *shells* and *fish*,	2154
e.	*Brown sandstone* (39′) with fossil *shells* and *fish*,	2168′
	Iron ore in sandstone (8′) with shells,	at 2213′
	Iron limestone ore (12′) and crinoids,	at 2229′
f.	*Red lime-iron-ore* (11′); with *fish*,	2261
	Limestone crinoidal bed (4′),	at 2319′
g.	*Green sandstone* (8′), with *fish*,	2358′
	Shell conglomerate (3′)	at 2658′
	Fossil limestone (2′),	at 2943′
	Black shales with plants (50′),	at 3208
	Abundantly fossiliferous shales,	to 3901′

We have here seven different horizons of fish remains, in two groups, separated by 270′; upper group included within 1779′–1843′, 64′, with a few red rocks; lower group included within 2100′–2366′, 266′, with all the rest of the red rocks in the section. This lower is the *Mansfield group of red bed in No. VIII* of the various reports. The fish in the upper group, *a*, *b*, are undetermined. Those of the lower group are probably :—*c*, *Bothriolepis* ; *d*, *Bothriolepis* ; *e*, *Holoptychius* ; *f*, *Bothriolepis* ; *g*, *Pterichthys rugosus*.*

Fish remains have been found in other places in Brad- county.†

* Of course there maybe other horizons in the Catskill (which reaches half way upthe mountain) of which nothing is as yet known.

† For instance : In Canton township, at the head of Towanda creek (8 m. W. of Leroy), two or three miles south of Canton, an *iron ore bed*, mined on the west bank, east of Ichabod Sellard's, (dipping N. W.) and the same ore bed three-quarters of a mile north of Sellard's holds *shells* and *fragments of fish* of apparently large size, and undescribed species (G, 86).—At Leona, on Leonards creek (10 m. N. of Leroy), in the Blossburg synclinal, *Catskill bottom red beds* appear holding *fish remains* (on J. P. Doane's lands).—At East Smithfield (G, 49) on Mitchell's branch of Tom Jack creek (14 m. N. N. E. of Leroy), the western hill top has sandstone and soft shales, gray, with *fossil shells* (23′ thick): *Calcareous* gray sandstone with *fish remains* (1′); red shale with *fucoids* and *ferns* (*Cyclopteris ?*) (3′); concealed (3′); shales and sandstone, gray, with *ferns* (2′); reddish shaly sandstone, cross bedded (12′) ; soft gray shale (9′)=(53′).—The dip is south into the Blossburg synclinal ; a mile north, and therefore lower in the series are beds of reddish shaly sandstone, over gray shale.—Red outcrops run to the river

VIII–IX. Tioga county fish beds.

Fish conglomerate, with *Holoptychius plates*, near Blossburg, underlies the base of the *Olean conglomerate* (XII) about 1740′.* This *Red Rock fish bed* (described in G, p. 48) appears on the Tioga Valley railroad, midway between Blossburg and Covington (2¼ m. N. of Blossburg, 6½ m. S. of Mansfield) in the cut through the so-called Red Rock, dipping 6° to 8° (S. S. E.), a place noted among collectors for its fish fragments. Scattered specimens may be found in all the strata from top to bottom for 200′; but they are numerous only at one horizon, between a calcareous layer and a bed of red shale. Here *perfectly preserved bones, scales, and teeth, still retaining their enamel, and in a measure*

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and appear 2 m. N. of E. of Smithfield; they appear (dipping N.) 2½ m. W. of S. of Ulster village, and here hold *fish remains.*—Monroeton on Towanda creek is 12 miles east of Leroy and 3½ from the Susquehanna river. At the bridge a mile west of Monroeton is an exposure of *red shale and sandstone with fragments of fish bones* (*Holoptychius* ?) 30′ thick; overlaid by gray shale and *calcareous* layers holding *fossil shells* (40′); and underlaid by similar gray shale and sandstone, and *calcareous* layers holding *fossil shells* (40′)=(110′), G, 26. The dip here is sharp to the south into the Barclay (Towanda mountain) synclinal. The red rocks at the bridge at Monroeton may be the same or lower beds. The whole outcrop may be identified with the Leroy *upper fish group: base of Catskill.*—At Wyalusing, on the Susquehanna (11 m. S. E. of Towanda, in an air line) just east of the railroad station a quarry section shows *fish remains* and *plant stems* in two or three *calcareous layers* in a series of gray sandstone strata, 55′ thick; under which lies a bluish *lime shale* (4′) with *fish bone fragments;* then gray and bluish sandy shale (4′); red shale (8′); bluish gray sandstone (6′)=(77′). This is a north dipping Chemung exposure at least as low as the lowest fish beds at Leroy (G, p. 27).—Fish bones in a red rock have been found at H. Parks' house in Standing Stone township, east of the Susquehanna river; and the upper Chemung and lower Catskill occupy the high land southeast of Wysox creek, into Orwell township (G, 50).

*Prof. White's section (G 5, p. 72) is longer than preceding geologists have made it. He makes XI, 245′. Evans in Geol. Pa., I, 520, made it 238′. *Sub-Olean* (?) buff massive sandstone, 20′. Interval from Blossburg to near mouth of East creek, N. 30° W. about a mile, dipping nowhere less than 6°, often 8°, 500′. *Pocono sandstone* (X) gray, 25′; *Calcareous breccia* 3′ (say 800′ beneath XII); gray, 25. *Catskill red shale, etc.*, 35′; sandstone, greenish gray, current bedded, 15′; shale, 5′; sandstone, as above, 40′; *interval* (shale ?) 250′; sandstone, greenish gray, finely laminated, 30′; *interval*, 50′; sandstone, greenish gray, current bedded, 20′; *interval*, 350′; *Red shale and sandstone*, 35′; *Fish conglomerate*, 2′; *Red shale and sandstone* on the railroad at the Red Rock, 200′. From this down *Chemung strata concealed.*

even their lustre, abound. The scales are all highly ornamented and measure from ¼ inch up to 2 inches and more in diameter, according to the species. The teeth are some of them an inch in length. The genus *Holoptychius* prevails. (G, 49).

From the Red Rock northward to Canoe Camp (1½ m. S. of Mansfield) on the Tioga river, 5 miles, Chemung rocks keep rising gently; and then, passing horizontally over the Wellsborough anticlinal, fall gently northward another 5 miles to Lamb's creek, where the *fish beds* go under water in the Crooked creek synclinal. Here Seeley's creek, a branch of Lamb's creek (4 miles N. W. of Mansfield), gives a section of *Catskill* lower and *Chemung* upper strata showing a *Holoptychius bed* near the top; another *fish bed* 84′ lower; and the *Mansfield upper ore bed*, about 170′ beneath it. (G, 79).

This *Seeley's creek upper fish bed*, is a stratum of red shale somewhat mottled with green, 4′ thick; containing calcareous layers; with *fish*, *plants* and *shells*.* *Fish* abundant, but many easily escape notice, as they can only be seen by carefully removing the shale which closely adheres to the thin calcareous slabs. Mr. Sherwood knows no locality in the northern counties so rich as this in remains of *Holoptychius*, *Bothriolepis*, *Dipterus* and other large armoured fish of Catskill age. The tooth on which Dr. Newberry established his *Dipterus sherwoodi* was found here.† Imperfectly preserved *scales*, rhomboidal or rounded, thick and strong, with surface punctate like European *Dipterus*, are numerous. There is no certainty that this *Seeley's creek bed* has any connection with the *Red Rock bed*, ten miles south of it; but there can be no doubt that they oc-

*The shells are not characteristic. The larger part of an *Orthonota* was found in it. Among the plants an equally well marked *Sphenophyllum* (perhaps *antiquum*). About 50′ beneath it a *Lingula* was found.

†See description and figure in Geology of Ohio, Vol. I, Part I. Palæontology, p. 61; and G, p. 80, foot note. Tooth one inch long, triangular, etc., apparently one of the upper palatal teeth; first of this genus found in America; readily distinguished by the small number of its radiating ridges. In 1874 this *Dipterus* tooth was found and simultaneously the first known *Ctenodua* tooth in Ohio Coal Measures.

cupy the same horizon, near the base of the Catskill formation.*

The *Seeley's creek lower fish bed* (50′ beneath the upper) is only 6 inches thick, between a roof of red shale (20′ thick) and a floor of gray sandstone (12′), and more such alternations of red and gray for 150′ lower. It is rich in ten or twelve species of *Upper Chemung fossil shells*, associated with *fish teeth* and *crinoidal fragments*.†

On Cowanesque creek, in May, 1841, I picked up from the roadside a specimen of *Holoptychius*, about 5 inches in diameter, consisting of one large dermal plate, surrounded by the attached borders of five or six others. Its original place had been on the hillside above the road somewhere near the lower limit of the red rocks. The fish beds of the *lower Catskill* therefore spread northward into New York.‡

On Elkhorn creek (which flows east into the Tioga river, at Tioga village) *Upper Chemung strata* are well exposed dipping (S. E.) into Crooked creek synclinal; gray and bluish, sandstone shales, with *calcareous* layers. Here Mr.

*In this ten milec the formation has become thinner, and the fish may not lie here much more than 1000′ beneath the *Olean conglomerate;* but there is no way of measuring the interval; for the top of the mountain is of Pocono rocks. Twelve miles west of the river, the first small patch of *Olean* preserved from erosion appears. Ten miles further west, near the Potter county line, the *Gaines basin coal beds* lie in summits of 2260′, 2240′, 2220′, 2160′, etc., A. T. Pine Creek railway grade at the mouth of Long run a mile below Gaines is 1240′ A. T. (See map in G, 3). The mountain range is a thousand feet high at Pine creek. Tioga river cuts across it at a somewhat lower level, viz: (RR. grade) at Lamb's creek, 1111′, Mill creek mouth 1077′, Tioga, 1042′ A. T. (G, p. 5).

† Just below Lamb's creek on the Tioga river, 3 miles N. of Mansfield, 138′ of red and gray alternations naturally belonging to the *Catskill*, hold *Chemung* fossils,—*Spirifer disjuncta* at the top, *Rhynchonella*, *Lingula*, and *Grammysia elliptica* at the bottom (G, p. 81).

‡ I cannot now give the exact place where I found the specimen, but it was not far west of Knoxville, 16 m. W. of the Tioga river and only 2½ m. S. of the New York state line. The specimen as I saw it from horseback looked like the back of a small land tortoise. It was packed with my first collections of that season's field work, all of which were lost before reaching Philadelphia. The first discovery of *Holoptychius* was in England.

Sherwood found the *fish tooth* named by Dr. Newberry *Heliodus lesleyi.**

Opposite Tioga village there is a fine railroad section of Upper Chemung strata) 784′ in all; and a calcareous *fish bed* with *plants* and *shells* (3′) 289′ down from the top. Under it are gray shaly sandstone layers (6′); and then a heavy (iron) reddish rock (1′) which may represent the *Mansfield middle* (*fish bed*) *iron ore* next to be described (G, p. 88. The section is given in full in White's chapter on the Chemung in Tioga county).

The Mansfield (*middle iron ore*) *fish bed* lies in Upper Chemung shales, about 400′ beneath the Catskill Red Rock holoptychius fish bed described above.† It is seen on Mann's creek (S. bank) a mile from the Tioga river, and just above D. H. Clark's, as a worthless iron ore bed, a foot thick or more, holding *fish remains.*‡

The Austinville fish bed is an oölite iron ore, very fossiliferous and yielding large numbers of *fish remains* most of which have been sent at various times to Prof. Hall, and

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*Geol. Ohio, 1875 (Part 1, Pal.), p. 64. It is properly a dental plate, rounded, 1½ inches long and broad, with a central semicircular smooth base, from which radiate eight ridges (set with tubercles) four on each side of a deep middle grove. *Heliodus* belongs to the same group as *Dipterus*, *Ctenodus* and *Ceratodus* : but in *Dipterus* the upper teeth are right angled triangles (half open fans), lower teeth longer (fan two-thirds open); in *Ctenodus* the ridges are more compressed and tubercles sharper ; in *Ceratodus* the teeth are smooth, ridges few and large, without terbercles ; in *Heliodus* upper pair of palate teeth firmly joined in one plate (fully opened fan) with radial tuberculated ridges like *Dipterus*. All these teeth are of true bone, and the tubercles are tipped with enamel. (G, p. 87).

† Mr. Sherwood says indefinitely 200′ to 400 (G, p. 61) ; but Mr. Lilley's Gulf Brook section at Leroy on Towanda creek in Bradford county, 20 miles southeast of Mansfield makes the interval 400′. It is possible however that the thinning of all the measures may diminish the interval on the Tioga river. Moreover we cannot take for granted the identity of the beds.

‡ It is opened on G. R. Wilson's hill, Whipple's hill, Bixby's hill, west and south of Mansfield ; Oak hill ; J. B. Clark's hill, east of Mansfield ; and in Sullivan township on Clark's, Rumsey's, Richmond's and Aldrich's lands; also at Roseville in Rutland township (7½ m. N. E. of Mansfield) and Wood's (1½ m. further N. E.); shows at Budd's in Columbia township, Bradford county ; and has been a good deal mined at Austinville (1½ m. E. of the county line, and 10½ E. of Mansfield); and further southeast near the N. C. RR. These places are described elsewhere and it will be seen that we have no certain proof that the same bed appears at all these places.

are now in the State Museum in Albany, or in the museum in Central Park, New York city. In 1874 specimens were sent to Prof. Newberry who pronounced them new. They are generally fragmentary, mostly bones (few if any scales or teeth), showing white against the dark red ore ground, and indicating fish of a large size. (G, p. 65).

The Mansfield lower ore bed (100′ to 200′ beneath the middle ore bed *) where it crops out in the bed of the Tioga river contains flattened pebbles of quartz, but no fish remains. We shall see in studying the Gulf Brook section at Leroy that there are several fish beds in the Mansfield division of the Chemung formation; and none of them can be assumed as persistent over a whole district; much less can be adopted as a key rock or plane of measurement.

Potter county fish beds.

The Allegheny river cuts a trench into Potter county about 600′ deep; the highland summits on each side being 2100′ to 2300′ A. T. The stratification is nearly horizontal; no dips greater than about 2° (two degrees) toward the N. N. W. and S. S. E.; the anticlinal and synclinal axes running within three or four miles of each other; so that any observed stratum on an anticlinal axis sinks to a level 600′ or 800′ lower at a synclinal axis.

Pulpit hill, which rises from the north side of the river just west of the McKean county line, is capped by soft greenish flags (2125′ A. T.). Five hundred feet lower red shales are exposed (1535′) and under them (1510′) greenish and reddish shales holding *minute plants;* under these (1490′) greenish massive hard sandstone (4′ thick) with *iron balls*, *plants* and bits of *fish bones* or *plates* (G3, p. 97).

At Fishing creek mouth, Roulet, two miles east of county line, in a railroad cut, the same (?) sandstone (with thin irregular conglomerate layers) contains *fish* fragments. (G3, p. 102). Here the river crosses the Roulet anticlinal; but the dip is gentle to the northwest. The rock is not a con-

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* According to Mr. Sherwood, G, p. 61. The place is "back of Shaw's, about a mile from D. H. Clark's middle ore bed opening," and of course on the anticlinal arch.

glomerate, but pebbles of quartz are noticeable in some of the layers. Others contain *plant stems* like the reeds of Coal measures (*calamites*), *shells*, and *fish* remains. The reed-like plants in particular are quite numerous. The locality is on the railway about half-mile below the mouth of Fishing creek. (G3, 30).

At Coudersport, 7 miles due east of Roulet, the mountain top south of Mill creek is made by the Olean conglomerates (top 2275′ ?). Two hundred feet lower (2070′) a terrace.* Nearly a hundred feet lower (1990′) Catskill red micaceous sandstone fragments; red soil at 1960′; red shale at 1940′; greenish-gray flags (exposed) at 1870′; red soil at 1780′, 1720′; carbonaceous sandstone (3′) at 1665′. Three or four feet over this lies a local layer (1½′) of calcareous shale, a sandy clay bed, rotten and iron stained.

The opposite mountain top, north of Mill creek (2550′) is also Olean conglomerate, the base of which is well marked at 2200′ A. T.; seventy feet lower (2130′) is a terrace top of *Sub-Olean*; at 1810′ is the *base of a quarry* in greenish-gray micaceous, laminated flagstone.† Water level at the tannery, 1675′ A. T. Red shale occupies much if not most of the last hundred feet; and it looks as if the fish bed of Roulet and Pulpit Hill lay several hundred feet beneath the river at Coudersport; for at Roulet on the anticlinal it lies at 1510′, and ought at Coudersport in the synclinal to lie at, 1400′ or 1300′, i. e. eight or nine hundred feet beneath the *Olean conglomerate*.‡

At Lamont summit, five miles north of Coudersport, on the Roulet (Hebron) anticlinal, the surface (2270′ A. T.) is red shale apparently two hundred feet deep, for at 2080′ red shale lies on greenish flags holding a three inch flat pebble conglomerate layer, with *fish bone* fragments. An average S. dip of 75′ to the mile for four miles would put

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* Covered with fallen fragments of fine, yellowish, irony, rather massive sandstone exactly resemble the *Sub-Olean* of eastern McKean county (98).

† Same as at 1870′ in the hill south of Mill creek. Another quarry in the same rock is worked, west of Coudersport; base of quarry 1795′ (G3, 99).

‡ The highest fossil horizon however in Ohlen Well No. 3, is at least 1500′ or 1600′ beneath the Olean conglomerate.

this on the Coudersport synclinal axis at 1780′ A. T. and identify these flags with the Coudersport quarry flags which they somewhat resemble in character. If so, this *Lamont fish bed* lies only about 450′ beneath the Olean conglomerate; or about 400′ above the Roulet fish bed.

Hebron mountain, seven miles N. N. W. of Coudersport, occupying the Oswayo synclinal next north of the Roulet-Hebron anticlinal, has a summit (on the Hebron-Clara road) only a hundred feet higher than the red shale at Lamont (2360′ A. T.) eighty feet beneath which is a quarry (base 2280′) in hard, rather massive, flaggy, greenish-gray Pocono sandstone, very false bedded and specked with mica, at least 8′ thick, with red shale roof soil. The Sub-Olean may have been eroded from the summit;* but at 2250′, descending south to Hebron, conglomerate fragments lie on the hill slopes which may be Sub-Olean; and large angular blocks of conglomerate are strewn around Hebron which greatly resemble the McKean Sub-Olean, and have probably come from the Hebron mountain.—Going north from the 2360′ summit, another 2320′ summit is crossed, and then the road descends to the low lying Sharon country of Chemung rocks. The first red soil is seen at 1960′. At the foot of the steep descent (1695′) red shale overlies an exposure of gray flags. From Clara to Sharon Centre most of the way is over red shale soil. The saw mill dam half a mile west of Sharon Centre is 1525′, and Oswayo creek 1492′ A. T. Here dark fragile olive shale (25′) overlies dark brownish-red shale (5′) very ferruginous and micaceous, holding fossil shells of Chemung type. Allowing only 20′ per mile for dip southwards, six miles, this fossil stratum must lie 1000′ beneath the Hebron mountain (road) summit, and more, if the dip be greater.

Hebron village is said to be about 2100′ A. T. A well record gives the depths (and thicknesses) of seven "sands"†

*No red shale has been seen immediately beneath the *Sub-Olean* anywhere in northern McKean county (G3, 100).

† Unfortunately the elevation of well mouth above tide is not stated. I assume it is at 2060′ A. T., and add to each well-depth 300′ to give the supposed depth beneath the Hebron mountain summit as 3000′.

730′ (20′); 1060′ (15′); 1110′ (120′); 1360′ (10′); 1402′ (16′); 1523′ (15′); 1580′ (3′ to 6′ at bottom).*

In Bingham township (Potter county) near the S. W. corner, on Middle Branch Genesee river, at L. P. & W. saw mill, are exposed: greenish gray, light gray and reddish sandstone and red and greenish shale, 50′; in the light gray and greenish sandstones *fucoid* impressions; in the false bedded reddish sandstone *fish remains;* in the greenish shales *fish remains, plant stems,* traces of *ferns;* lowest Catskill rocks. (G3, 57).†

*The so-called "sand" (20′) is said to have been really an impure limestone; lying probably about 700′ lower than the conglomerate blocks on the mountain, it recalls to mind the calcareous rotten rock at Coudersport, 600′ beneath the mountain top there. But our data is so poor that such comparisons are of little or no value (G3, 79). No oil was got in this well; and the distinction of "sands" and "intervals" must be taken with hesitation.

† *Fish scales* have been found in other parts of Potter county; for example, in Stewardson township (bordering on Clinton and Tioga counties) *Lower Catskill* thick bedded red sandstones, crop out on Kettle creek, at Anderson's saw mill (1¾ m. above mouth of Cross Forks) and over them, alternations of red and green shales (dip N. W.) holding *rhomboidal fish scales* an inch or more in diameter. No Chemung rocks come up along the anticlinal to the north. The synclinal mountain is capped by Olean conglomerate (XII) lying perhaps 1000′ above the fish bed (G3, 17).—In Wharton township, where the Nelson coaly sandstone appears on the Sinnemahoning, over red shale, as described in another place, Chemung fossil shells show imperfectly in gray shales along Sinnemahoning creek road 1½ m. N. of the Clinton county corner (Swartwood's); and again a quarter of a mile further up stream where a brook crosses the road, in loose fragments, in one of which Mr. Sherwood got a large fish bone. This is so near the New Bergen anticlinal axis that this fish horizon must be at least 500′ beneath Nelson's coal bearing sandstone (described elsewhere) and therefore at least 1500′ beneath the Olean conglomerate. This would agree with the upper "fossil horizon" in the Ohlen Well No. 3; but not with the Pulpit and Roulet fish bed horizon already described and estimated to lie less than 1000′ beneath the Olean conglomerate. But the finding of one fish means nothing; millions must exist at all levels throughout the Catskill and Chemung formations. It is only where they occur in numbers together and with plants and shells and quartz pebbles that they constitute a geological horizon; and even then we have no certain data respecting the lateral extent of any such local accumulation; nor do we comprehend yet how such accumulations were produced. But the contrast is very remarkable between the numerous depths at which fossil shells were brought up from the Dennis well near Bradford in McKean county, and the few that were got in the four Ohlen wells in Potter county.

Queen's Run fish bed, Clinton Co.

The *Queen's run* red conglomerate fish bed in Clinton county, appears in the gorge of the Susquehanna West Branch above Lock Haven, lying 1844′ beneath the base of the Olean conglomerate (Pottsville Cong. No. XII) thus :—

XI. *Mauch Chunk red shale*,		100′
X. *Pocono* gray sandstone and shales,		1175′
IX. Catskill *red and gray sandstone*,	569′	
" *fish bed*,*	2′	
" red sandstone,	1534′	=2106′
VIIIg. Chemung shale, olive and gray,	347′	
" " olive, gray and red,	538′	
" " dark gray,	455′	
" " gray and red,	409′	=1747′
VIIIf. Portage residue down to *Genesee*,		1567′

Queen's run is 35 miles S. S. E. from Ohlen Well No. 1 in Potter county ; and 50 miles S. W. from the Red Rock Holoptychius bed near Blossburg, Tioga county, where it lies 1700′ beneath No. XII. The coincidence may be accidental, but it is striking, and may be important†.

Fish beds in Lycoming county.

The Larry's creek iron ore fish bed in Lycoming county, 14 miles east of Queen's run,* averages 2′ thick, and contains fossil shells and fish remains. The beds here stand nearly perpendicular on the north side of a sharp anticli-

* In Dr. Chance's long section (Report G4, 126) the bed is described as a composite of sandstone and limestone (?) pebbles and concretionary balls of iron ore, 2′ 4″ thick. The complete section is given elsewhere.

† It can hardly be supposed that this is the only fish bed in the Catskill and and Chemung columns at Farrandsville. A dozen such may crop out at various heights in the mountain walls between which the Susquehanna West Branch breaks out from its long gorge through the Allegheny mountains above Lock Haven. No safe reasoning can proceed on such negative evidence. Mr. Lilley's section at Leroy (Gulf Brook) has taught us a never-to-be-forgotton lesson ; for until that section was made only a single fish bed was known along the Towanda mountain ; and only three were certainly known along the Tioga river.

* Secrist's, Borger's, Miller's mines along Canoe run, which enters Larry's creek from the west 3 miles N. of Larry's creek railroad station on the river (G2, p. 39).

nal axis. On Pine creek (5 miles west of Larry's creek) 1200′ to 1500′ of red Catskill rocks plunge north from this anticlinal. The ore bed underlies these in the Upper Chemung, and therefore occupies the Mansfield or Leroy fish horizon. The distance from Larry's cr. mines to the Red Rock Holoptychius bed near Blossburg is 32 miles (N. N. E.); and to the Leroy fish beds of Bradford county it is 38 miles (N. E.). For this whole distance the top of the Chemung stays underground.

The *Muncy creek fish horizon* at the east end of Lycoming county (33 miles east of Larry's creek and 30 miles south by east of Leroy) is a group of *red* shales, 10′ of which are visible ; some of the layers filled with fish remains, mostly scales and teeth, generally fragmentary and apparently belonging to *Holoptychius*. This excellent locality for collectors is at Biggar and Camp's saw mill, a mile above the mouth of Indian Camp creek on Little Muncy creek in Jordan township. The dip is northward towards the Allegheny mountain highland of Sullivan county, which spreads at an elevation of 2300′ to 2400′ A. T. (G2, pp. 58, 209). The fish horizon is undoubtedly near the contact of Chemung and Catskill, and corresponds to that at Leroy ; but no measurements up to No. XII have been made.†

†The upland is *Pocono* (No. X) upon *Catskill*. The *Chemung* occupies the wide anticlinal cove-like low-land around Lairdville and Unityville, spreading into Columbia county. On Little Muncy creek red rocks appear at the bend just above the mouth of Indian Camp creek ; and under them (in the bend) 25′ feet of gray Chemung shales. The same (?) red rocks (20′) appear at Crouse's upper mills, 2 miles further west; and again (30′) a half-mile further, at Vandine's saw mill, mouth of Beach Bottom run. Other much lower red rocks appear at Crouse's lower saw mill, 1 m. above Lairdsville ; but at Lairdsville grey Chemung rocks and so down the creek on the gentle north dip. The red belt must be several hundred feet thick at Leroy. It is not to be taken for granted that the fish horizon is any farther underneath No. XII here than at Leroy or at Queen's run.

CHAPTER LXXXXVIII.

VIII g. Tioga and Bradford Co. fossil collections.

In Tioga and Bradford counties, Pa., large collections of Chemung fossils were made by Mr. Sherwood, which were labeled and catalogued by C. E. Hall, reviewed by Mr. Simpson, and many of them submitted for verification to Prof. Jas. Hall, and the list republished in Report O3, as a special catalogue of fossils on pp. 220 ff. Of course Vanuxem's and Hall's species are largely represented, the New York state line being so near.

I place them in alphabetical order for convenient reference:

Ambocœlia umbonata, numerous; also its variety *gregaria.*—*Atrypa hystrix*, numerous at Tioga city, Mansfield, Lawrenceville. Dorsal valve of spec. 860–52 suggests a new species.—*A. reticularis*, not common.—*A. impressa*, *A. spinosa*, very numerous casts at various places, one slab covered with them.—*Athyris angelica*, many casts showing scars, pustulose surface, etc. Beak shown in spec. 854–37; shell preserved in spec. 856–42; occurs in iron ore bed high in the Chemung (O4, p. 249). *A. pseudomarginata.*—*Aviculopecten cancellatus*, a fine spec. 855–22.—*Bellerophon triliratus*, 850–30. *B. maera* many casts.—*Byssopteria radiata*, 850–29.—*Chœtetes.*—*Chonetes scitula.*—*Cœlospira concava ?*—*Cyathophyllum* calyx ?—*Cypricardites* (*Schizodus*) *rhombeus.*—*Cyrtina triplicata.*—Crinoidal stems and joints covering a slab, 872–53; beautifully sculptured, 388–19.—*Discina ampla*, a doubtful specimen found at Mansfield.—*Dictyophyton*, a small fragment from Mixtown.—*Edmondia philipi*, good right and left valves. *E. obliqua*, *E. subovata*, good specimens from several places.—*Euomphalus* (*Straparollus*) *cylmineoides.*

Fish remains, mostly in the shape of badly spoiled skin plates or as merely obscure white blotches on the surfaces of the strata, are abundant in many places in our northern counties, along geological horizons which are established at only a few places, notably at Mansfield on the Tioga river, and near Leroy on Towanda creek (Gulf creek section). Sherwood's collections at Lawrenceville, Mansfield, and Seeley's creek in Tioga Co., contain skin plates (O3, Nos. 901–1 to 6); scales with concentric lines and punctate, spines, and teeth ; several individuals on one slab (Nos. 900–1 to 10). At Logan Station, Lycoming Co., bones, head plates and teeth (No. 893). Others at Meshoppen, Wyoming Co., East Liberty, Bradford Co., and Roulette, Potter, Co.

Goniophora chemungensis, common.—*Grammysia elliptica*, abundant everywhere, some of large size.—A *Hederella* in the Mansfield ore bed (O3, p. 251).—*Leiopteria dekayi*.—*Leptodesma demus*, *extenuatum*, *lepidum*, *lichas*, *longispina*, *mortoni*, *naviforme*, *phaon*, *potens*, *propinquum*, *protextum*, *robustum*, *stephani*.—*Lingula punctata ? Loxonema terebra*, numerous, but mostly poor impressions.–.*Lyriopecten tricostatum*.—*Modiomorpha quadrula* in McKean Co.; *M. rigidula*, Simp. in Tioga ; *M. subalatus* var. *chemungensis*.—*Mytilarca chemungensis ; M. occidentalis*, not only in Tioga, but in Erie, at LeBoeuf quarries.—*Mytilops metella*.—A *Nuculites*.—*Orthis impressa*, everywhere, often finely preserved ; *O. leucosia*, and its variety *pennsylvanica*, Simp. (whose type is in Randall's McKean collection) got from many places ; *O. vanuxemi*, LeBoeuf quarries, Erie Co.—An *Orthoceras*.—*Paracyclas tenuis ? ;* (*Edmondia*) *subovata ?*—*Pleurotomaria sulcomarginata*.—*Productella arctirostrata*, everywhere abundant ; *boydii*, everywhere numerous ; *exanthemata*, numerous in places, in company with *hirsuta ; lacrymosa*, numerous in many places ; *onusta*, also in Erie Co.; *rarispina*, at Linden, Lycoming Co.; *spinosa*.—*Pterinea chemungensis ; consimilis ; flabella*.

Plant impressions are numerous in some localities (Big Shanty, McKean; Meshoppen, etc.,) both *Fucoids* and *Lepidodendrons*. One slab is covered with small oval knobs ; another similar from Tioga ; also an *Archæopteris ;* and *Arthrophycus harlani*. *Pterinopecten suborbicularis* in several places.—*Ptycoparia salamanca* on Kinzua creek.—*Ptycopteria falcata*.—*Rhynchonella altiplicata; R.* (*Steno-*

chisma) congregata, Erie Co.; *contracta* numerous in many places (a variety, at Middletown); *duplicata* in various places; *eximia* widely distributed, numerous in Lycoming, Potter and Bradford; *orbicularis; sappho*, numerous in many places.—*Schizodus rhombeus.*—*Spathella typica?*—*Sphenotus contractus*, one very narrow specimen; *chemungensis*, Simpson; *clavulus.*—*Spirifera disjuncta*, in immense numbers everywhere, at no fixed horizon;* *S. granulifera; S. mesocostalis* in great numbers in some places; *S. mesostrialis* is wanting from this northern region if we may judge by the fact that not a single specimen of it is found in the collection; *S. mucronata; S. præmatura.*—*Streptorhynchus chemungense* numerous everywhere.†—*Strophodonta cayuta*, numerous; *inæquistriata*, abundant at Lawrenceville, 20 or 30 on a slab, both valves, casts, impressions, among fragments of other fossils; mostly casts of interior showing the scars; one hinge an inch long; not obtained elsewhere; *perplana* var. *nervosa* (many ventral interiors at Mansfield, No. 860–27 beautifully showing hinge crenulations and muscular scars; 883–13 Nichols shows the scars finely).—*Strophomena concava* (one cast at Lawrenceville); *rhomboidalis* (one at Tioga, but nowhere else).—*Triplesia extans* (*Athyris angelica?*)—*Tropidoleptus carinatus.*

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*In Charleston a small specimen covered with small casts; one occurs with three individuals of Athyris angelica; sometimes the hinge line is not extended; many slabs are quite covered with casts; No. 869–18 is a peculiar cast; 870–3 is semicircular; 883–46 is very transverse; at Nichols, Tioga Co., N. Y., Nos. 872–7, a, b, show it in company with Sp. mesocostalis, Atrypa reticularis, A. spinosa, Athyris angelica, Strept. chemungense, and crinoidal columns. Another slab shows only Sp. mesocostalis with A. retic. and crinoids.

† No. 852–3 with unequal striæ; 855–1–2 good dorsal valves; some narrow and regularly rounded, some broad, slightly convex with a slight sinus, some flat, others convex with a sinus, others rounded with a sinus, some small and flat, 855–366 showing the scars; some in company with Orthis impressa; 856–15 and 49 with alternating striæ; No. 860–11 in company with ventral valve of a *new species;* 860–60 large casts with Orthis impressa; 860–85*a* shows the ornamentation of the hinge line and the muscular impression; *d.* shows the scar very prettily; most of the specimens seems to be of the flat valve; No. 883–59 is a slab containing many impressions; 883–94–2 is an interesting slab showing the various phases of the species.

CHAPTER LXXXXIX.

*VIII and IX in the four Ohlen Wells of the Germania Oil Co. in S. E. Potter county.**

An unusual opportunity for studying minutely the character of part of the Chemung and overlying Catskill formations, was afforded by a careful comparison of the drillers' records of the four so-called Ohlen Wells bored to reach the Bradford Oil Sands (see Annual Report of the Survey for 1885, p. 85).

Well No. 3, near the center of the basin, went through higher rocks than the others; and Well No. 1, on the anticlinal, through lower rocks than the others; by uniting them we may get an illustrative section of nearly 3000′ of *Catskill* and *Chemung strata*, as they exist beneath southwestern Potter county, thus:†

*Sunk in 1880–1, by the Germania Oil Company; called Ohlen well No. 1, No. 2, No. 3, No. 4. Records kept with unusual care, and sand pumpings every five feet, were contributed by Messrs. Ohlen & Chambers to Mr. Carll for the use of the survey (see Mr. Ashburner's report of them in Annual Report G. S. Pa. 1886, p. 84; and catalogue of the specimens in the museum of the survey, No. 10,735 etc.)

No. 1. Abbot township, 2 miles S. W. of New Bergen, on Cross Forks creek, mouth of Boligh's run, 16 miles S. E. of Coudersport. Height above tide *by barometer* (Chambers) 1530′, A. T.

No. 4. Abbot township, on turnpike, 1 mile N. E. of New Bergen, head of Little Kettle creek, 7 miles from Tioga Co. line, 1850′ A. T. (bar.).

No. 2. West Branch township, 5½ miles N. N. W. of New Bergen, on West Branch Pine creek; 1700′ A. T. (bar.).

No. 3. West Branch township, 5½ miles N. N. W. of New Bergen, (11¼ miles S. E. of Coudersport and 1½ miles north of the turnpike), on the high land in the center of the basin; 2050′ A. T. (bar.).

No. 1 and 4 are on the east of the New Bergen (Wellsborough) anticlinal; and No. 2 and 3 are in the Pine creek synclinal (Wharton coal basin of McKean; Cameron coal basin of Cameron; Fourth Bituminous coal basin of W. Pa.)—Dip from 1 and 4 to 2 and 3, N. W.—No. 1 to No. 4, 3 miles; No. 1 to No. 2, 4½ miles; No. 1 to No. 3, 5½ miles; No. 2 to No. 3, 2½ miles; No. 2 to No. 4, 3¼ miles.

†The anticlinal on which wells 1, 4, are bored runs southwest to the Potter-Clinton-Cameron county corner on Sinnemahoning creek, three miles below Wharton mills. The synclinal in which wells 2, 3, are bored, lies north of it, and its axis, or deepest middle line, crosses the Sinnemahoning a little

Ohlen Well No. 3. Well mouth, 2050 A. T.

Conductor hole, ...		40 to 40
Sandstone, yellowish gray, fine grained, hard,		30 to 70
Shaly sandstone ; and *red slate*, ...		30 to 100
Sandstone, gray, ...	5	
" *red* and dark grey, fine *micaceous*,	10	
" grey, shelly, 35′+35′+15′, . .	85	to 200

north of Nelson's run, three miles above Wharton mills (14 m. W. S. W. from well No. 3). The highest land at the head of Nelson's run is (by barometer) 2290′ A. T., and made by a patch of heavy sand-rock, which is either Sub-Olean, or Olean ; probably Sub-Olean. The trench of the Sinnemahoning is cut down to 1045′ A. T., exposing (very imperfectly of course) 1245′ of *Pocono* and *Catskill outcrops.* From the top down for about 1000′ everything has a grey look ; the bottom rocks are red. At various heights above the creek massive current-bedded sand rock layers are seen, but *no conglomerate :* not even as boulders swept from the highland ; a good proof that the synclinal does not preserve the Olean conglomerate, in this part of course. At 420′ above creek, greenish gray, very micaceous, thin bedded and current bedded sandstone. At 510′, the same, more massive. At 720, the same, massive. At 760′, the same ; and much coarser and still more massive blocks, among which was noticed (F. Platt) one small piece of white quartz *round pebble* conglomerate. From 760′ to 1245′ (top) nothing but small pieces of coarse and fine gray sandstone. Note, however, that hillsides thus covered conceal numerous shale partings and even larger shale formations, some of which may be *red*, and yet not noticeable (G3, pp. 90, 91).

As the above 2290 A. T. is only 240′ higher than the mouth of Well No. 3 (2050 by bar. A. T.), the level of the Sinnemahoning ought to come in Well 3 at about the depth of 1000′, if the synclinal axis were a dead level. But the contour lines connecting the four wells show a decided decline in both synclinal and anticlinal westward (how far continuing in that direction we know not) which would carry the Sinnemahoning water level higher up the well. If, as is probable, the anticlinal and synclinal axis rise and fall alternately along their course, the Nelson coaly sandstone may fall into the dark shale horizon of the wells. The aspect of the upper 1200′ of the well record is *red*, with numerous large gray intercallations. But the whole of this upper 1200′ is *sandstone ;* under which comes the *dark slate horizon.*

Now on the Sinnemahonning, 300 above the creek level, *coal was dug for*, at Nelson's Drift, a thousand yards south of Nelson's run ; exposing nothing but a sandstone layer, one foot thick, holding *thin streaks of coal* (with scattered small pieces of coal) on a layer of *fire clay*, one foot thick, holding one small *streak of coal.* Above and below the coaly sandstone are seen thin-bedded, current-bedded, gray and greenish sandstone formations, with some *red sandstone* and *red clay-shales.* From not far below the coal (50′ to 100′) down to water level "the whole mass is of *red sandstone* and *red slates*, with some gray and greenish gray layers."

Mr. Platt considers this whole section practically similar to that including the *Barbour's mill coal* on Loyalsock creek, Lycoming Co. But the distance between the two localities is too great to allow any dependence to be placed on so general a resemblance.

Shale stone, fine, clayey, hard, ...		20 to 220
Sandstone and *chocolate* sand-shale, ...		10 to 230
" gray, thin bedded, ...	10	
" gray, dark, fine grained, ...	35	
" thin bedded, ...	25	70 to 300
" " *red*, ...		20 to 320
" gray, ...	5	
" fine grained, *red*, ...	20	25 to 345
Slate and thin sandstone, ...		20 to 365
Sandstone, grey and *red*, ...		50 to 415
" grey (with some slate), ...		25 to 440
Sand-slate, *green* and *red*, ...	40	
Sandstone, *greenish*,, ...	10	
" green and *red*, ...	25	
" *greenish*, ...	10	
" *green* and *red*, ...	5	
" grey, ...	10	
" *green* and *red*, ...	5	
" gray, fine, ...	10	
" *green* and *red*, ...	5	120 to 560
" gray, ...	10	
" " bluish, dark, fine, ...	5	
" " yellowish, fine, hard, . .	90	
" " bluish, friable, ...	10	
" " yellowish (with some slate),	30	
" " greenish, ...	15	160 to 720
" shaly, *green* and *red*, ...		10 to 730
" gray, greenish, coarser, ...	35	
" " " finer, ...	35	70 to 800
" *gray* and *red* (shaly), ...	10	
" gray, ...	10	
" *gray* and *red*, ...	10	
" *greenish* (fine), ...	20	
" *grey* and *red*, ...	10	
" shaly, *red*, ...	40	
" yellowish (fine), ...	25	
" gray (fine), ...	25	
" " (fine and hard), ...	5	

Sandstone, *reddish* (fine and hard), ...	35	
" *reddish brown*, dark (some shale),	40	
" *red* (*dark red*), ...	5	
" *red* and *white* (fine), ...	15	
" yellowish (fine), ...	5	
" *red* and *white*, ...	5	
" yellowish, ...	25	
" *red* (shaly), ...	15	
" yellowish, ...	10	
" *red* (*dark red*), micaceous flaky,	30	
" yellowish (fine), ...	15	355 to 1155
Dark slate, and gray sand layers, ...	5	
" slate with gray sandstone, ...	10	
" slate, ...	5	
Sandstone, yellowish, fine, hard, ...	15	
Dark slate with sand layers, ...	25	
" slate, ...	15	75 to 1230
Sand layers, micaceous, light gray (with slate bed),		30 to 1260
Slate, muddy, ...	15	
" mud rock, and sand plies, 15+10=	25	
" muddy (?), ...	20	
" and sandstone plies, ...	25	
" with more sandy layers, ...	5	
" sandy, ...	75	
" dark and clean, ...	5	170 to 1430
Fossiliferous sandstone layers in slate, ...		10 to 1440
Dark slate, ...		10 to 1450
Fossiliferous sand layers in slate, ...		15 to 1465
Sandstone, *red*, flaky, micaceous, ...	20	
" *red* (with *dark* slate), ...	30	
" *brown*, flaky, fine, ...	25	
Shale, sandy, *red* (dark reddish brown), . .	35	
Sand layers (with dark and light slate), . .	15	
Sandstone, *brown* (with light gray layers),	10	
" gray, dark, slaty, ...	80	
" gray (in slate), ...	35	
" gray and brown (with slate), . .	45	
" gray (less slate), ...	60	
" *red brownish*, flaky, micaceous,	20	375 to 1840

Shales with thin sandstone layers, . .	80
Sandstone, light brownish, gray, micaceous,	20
Shales, micaceous, ...	25
Sandstone, brownish gray, flaky, ...	5
Shale, ...	20
Sandstone layers and shales, . . .	5
Shale, ...	155
Shale, sandy, ...	5
Shale, muddy, ...	20
Shale, more sandy, ...	55
Shale (to bottom of well No. 3.), ...	520=910 to 2750

It appears from the above record that Well 3 goes down through *Catskill red* and *gray sandstone beds* more than 1100′; then through *dark slate*, or shales, sandy, with sandstone layers, 75′; then alternation of shales, muddy and sandy, and sandstones, 300′; then two horizons of *fossiliferous sandstone beds* separated by shale, in all 35′; then a *lower set of red beds* (*Catskill-Chemung*) *red and brown and gray sandstones and shales*, 375′; and then almost continuous *Chemung shales* (with two or three unimportant sandstone horizons in the upper part), 910′.

The *dark shale horizon* is represented in Well 2, at 680′, 765′, in Well 4, at 300′+ as 120′ of sand layers and dark slate; and in the more western oil wells.

The *fossil shell horizon* of Well 3, does not appear in the records of Wells 1, 2, 4; it *overlies* the *lower red* by about 400′; but there is *another fossil shell horizon underlying the lowest red* about 1200′, which appears in Wells 1 and 4.*

It is impossible to mistake the general character of the formations as exhibited by a graphical comparison of the four well sections.

The *lowest red bed* is a curiously constant horizon. The establishment of this fact is one of the most gratifying rewards for keeping these well records so carefully that they can be compared with success from top to bottom. It is

* The *fossils* detected by the drillers at two horizons, 1000′ apart, are not described. They may have been broken shells, or broken fish plates. The lower horizon would probably yield Chemung shells.

represented in Well 3 by *light brown and red micaceous flaky sandstone*, 20′ thick (to 1840′); in Well 2 by *red and green sandy slate*, 5′ (to 1160); in Well 4 by *chocolate fine sand beds and dark slates* 55′ (to 850′); in Well 1 by *chocolate sandstone* 25′ (to 685′).

Starting with this well defined horizon in Well 1, we can now repeat and define more closely the lowest 910′ of Well 3 (given above), and add 434′ of still lower Chemung strata, thus:—

Ohlen section continued by Well No 1.

		Well 1.	Well 3.
Lowest red; chocolate sandstone, ...	25	to 685	=1840
Shale, dark, sandy, with sand plies, . . .	35		
Sandstone, fine, with slate partings, . . .	35		
Shale, with a few sand plies, ...	430	to 1115	=2270
Sandstone, light grey, fine, ...	10		
Shale, with a few sand plies, ...	255	to 1380	=2535
Sandstone, shaly, dark, fine, ...	20		
Shale, with dark sand plies, ...	40		
Sandstone gray, fine, ...	10		
Shale, gritty, ...	15		
Sandstone, dark, fine, ...	5		
Shale, gritty, sand plies, ...	60		150 to 2685
Sandstone fine, flaky, shale plies, . . .	105		
" fine; more mixed shale, .	35		
Fossiliferous shales (sand plies), ...	5		to 2830
Shales and thin sands, alternating, . . .	45		
Sandstone, bluish, flaky, fine, ...	15		
Shales and sand plies, ...	60		
Sandstone, brownish, fine, ...	10		
Shale, sandy, ...	5		
Sandstone, brownish, light, ...	5		
Shale, sandy, ...	5		
Sandstone, brownish, dark, ...	10		to 2985
Shales and shaly sand plies (bottom), . .	199		to 3184

No oil or gas.

Not a show of oil was seen in any of these Catskill and Chemung measures, from the top of Well 3 to the bottom of Well 1, although more than 3000′ were passed through; corresponding to the *Venango oil sands*, the *Warren oil sands*, and the *Bradford oil sands*. This proves conclusively that there is no oil country to the southeast of the known oil belts.

No conglomerate.

It is very remarkable that in all this 3000′ of strata not a trace of oil sand conglomerate, or conglomerate sandstone of any kind, coarse or fine, was passed through, although such gravel rocks were the oil-bearing strata for which the drillers were seeking and watching to find. There is no doubt therefore of the total absence of the upper and lower (Lackawaxen and Alegrippus) *Chemung conglomerates* of middle Pennsylvania; and of their representatives the First and Third *Venango oil sands*, in Potter county. It is probable that most of the so-called Chemung conglomerate exhibitions mentioned in the Report on Potter county (G3, 1880) are transported blocks, and that most or all of them have come from the synclinal mountain tops, which were once completely capped by the Olean conglomerate No. XII, and the Sub-Olean conglomerate No. X. I give the best defined instances in a footnote, the subject being of great geological importance, although a more proper place for such local description would be in coming chapters on Nos. X and XII.*

*In Hebron township, a mile S. E. of East Hebron. large masses lie 40′ above the creek; also, on the hill ¾ m. W. of Lamont; on the hill top west of D. Clark's, 1½ m. S. E. of Hebron, where they rest on red soil; also, in great abundance ¼ m. S. E. of Hebron; at Hebron, and all the way down Fishing creek to Roulet. In the S. E. corner of Clara township they are very massive and coarse. They are abundant along Sartwell creek valley in Pleasant Valley township next the McKean county line; and are of course *Olean* or *Sub-Olean.*—In Sharon township, ¾ m. N. E. of Sharon Center, the fields are strewn with masses of *white conglomerate sandstone* lying on outcrops of highest Chemung, or lowest Catskill. It is hard to understand how ice could bring them from the north (New York) where no Olean or Sub-Olean summits are. (Mr. Sherwood notes that he has seen such a conglomerate *in place* on the Genesee river between the N. Y. state line and Wellsville, N. Y., and therefore Chemung, G3, 52.) Nor could they come from the Hebron mountain tops to the south, except by a reflex glacier, which is not to be thought of lightly. They lie scattered over the country

Harrison well in Potter county.

The Harrison bore hole in the N. E. corner of Potter Co. (G3, p. 80), gives a less carefully observed section of the Chemung, from near the top of the formation (as conceived by Mr. Sherwood) downward for 1995′, its mouth being about 1620′ A. T. The uppermost 840′ of the record are all shales (some gas being noted at 392, and some salt water at 443); then sandstone, 55; then shales with some thin streaks of sandstone, 335; then a second sandstone, 50; shale, 170; sandstone, 10; shale, 143; sandstone, 7; shale, 65; sandstone, 70; shale, 185; sandstone, 4; shale, 61, to the bottom where the *hope of finding* oil was abandoned.

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between Sharon Center and East Sharon, mixed with loose gray stones. (The people have taken them XII and dug for coal.) These have come but a short distance; for gray flags crop out 1 m. S. E. of East Sharon; and thin bedded, oblique bedded, gray sandstone (with a few fossils, and an occasional quartz pebble) crop out 1½ m. N. E. of Shingle House, near the hill top (Jas. Sherwood's) north of Honeoye creek; of course Pocono or Catskill.—In Oswayo township, conglomerate boulders are strewn around Oswayo, but it lies in the synclinal, and they have come from the hill tops, Sub-Olean or Olean.—Genesee township occupies the same synclinal, where the Genesee river crosses it. The Roulet-Hebron anticlinal elevates gray (Chemung?) flags at Ellisville (in the S. E. corner) dipping N. W. and the red rocks (VIII–IX) first appear at a mile down stream; at two miles much red sandstone (IX) nearly horizontal; the gray flags and shale re-appear (with S. E. dip) a mile before reaching the Forks; no conglomerate blocks noticed.—In Bingham township red shale prevails (Catskill), with a few Pocono hills along the west line and in the south west corner; the streams cut into the top of the Chemung. Massive white sandstone boulders are seen ½ m. above the mouth of Turner's creek. Fish beds show Catskill (G3, 57)—In Harrison township, N. E. cornor of Potter county, the Coudersport synclinal becomes excessively flat and shallow, and the Catskill formation must be thin; all the hills being capped by red shale, except in the S. E. corner where Pocono summits lie in the Cowanesque synclinal. Loose stones in the Cowanesque creek bed hold Chemung fossil shells. A belt of red soil 100′ wide crosses the road 1 m. N. W. of Harrison valley, with whitish sandstone. Grindstone grits crop out in the creek bank at Holcomb's, a mile below the village, and over them gray shales hold badly preserved fossil shells. No conglomerate was noticed in the township.—In Hector township (next south, along the Tioga county line) gray sandstone boulders (Pocono?) are numerous on the Genesee Forks branch of Pine creek, a mile N. of the Pike township line; also 1¾ m. N. W. of Sunderlinville; still more abundantly 4 m. N. E. of that village (G3, 41).—In Ulysses township (next west of the last) no Chemung rocks are noticeable.—In Allegheny township (next west) Catskill red shale is abundant on both sides of the Coudersport

The Hebron well is in the N. W. quarter of Potter Co. (G3, p. 79). Here, according to Mr. Sherwood's view, the red Catskill rocks are only about 500′ thick, and the mouth of the well about 180′ below the base of the Catskill and 610′ below the base of the Pocono formation No. X. It went down first through shales, 430′; then through "impure *limestone* beds" 20, which may be the equivalent of the Mansfield or Burlington limestone of Bradford Co., and the Forksville limestone of Sullivan county; then shales, 310; sandstone, 15; shale, 35; sandstone (?) beds, 120; shales, 130; sandstone (?) beds, 10; shales, 32; sandstone, 16; shales, 105; sandstone, 15; shale, 42; sandstone, 3 to 6 feet, at the bottom; no oil or gas found; total depth 1286, all in Chemung.

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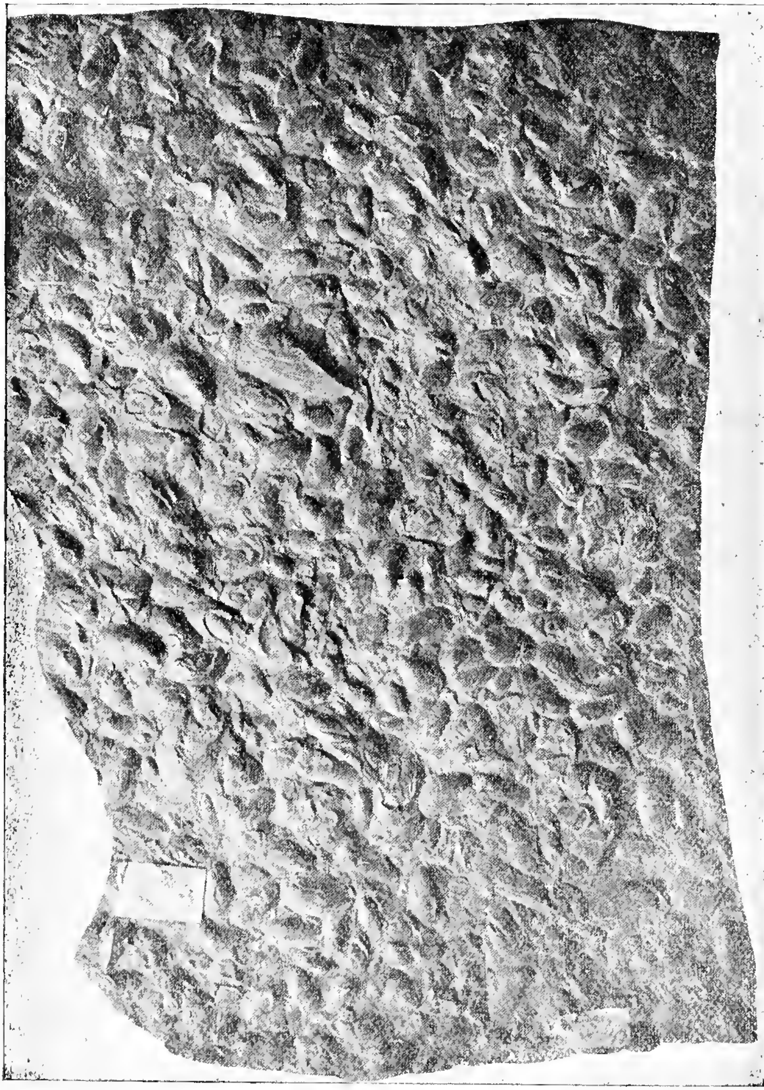
synclinal belt of Pocono hills. Boulders of Olean and Sub-Olean conglomerate are abundant on the mountain 2 m. N. W. of Raymond Corners; but no lower conglomerate can be found.—In Sweden township (next south of the last) the Olean conglomerate caps the mountains, but none appears in the lowland.—In Jackson township (next east of the last) Coal Measures are opened on Whitmore run, and the whole township is high Pocono and Catskill, except in the deep water course of Pine creek west of West Pike. Enormous blocks of Olean conglomerate have fallen to the low land.—In Pike township similar vast masses choke the gorge of Pine creek, which is cut through Catskill red rocks.—In West Branch township (next south along the Tioga county line) boulders of Olean conglomerate from the summit hills fill the valley bed in which Ohlen Well No. 2 was bored; no lower conglomerate appears at the surface; and *no conglomerate sandstone is noted in the records of the four wells,* which furnish a remarkably precise and reliable account of 3000′ of Pocono, Catskill and upper Chemung measures. This seems to settle the question as to the existence of any "Chemung conglomerate" of Potter county.

Chemung fossils. Leroy. Pl. CCII.



Chapter C.

VIII g, Chemung in McKean county. Bradford oil sand group. McKean oil and gas sand group.

The highlands of McKean, on which have been preserved patches of the lowest coal measures, reach a maximum elevation of 2500′ A. T. They are trenched by the head streams of the Allegheny river flowing northward across the New York state line, and westward across the Warren county line, where the Kinzua creek water-bed is only 1240′ A. T.*

As the streams flow north and the strata dip gently south the hill slopes expose the deepest stratification at the state line; and these beds are high in the upper division of the Chemung formation, leaving the bulk of the upper and all of its middle and lower division (according to Ashburner's classification) underground to be known only by more or less perfect records of innumerable oil wells in the celebrated Bradford oil field, and of many test borings to the south of the limits of that field.

For the *top limit* of the Chemung Ashburner adopted the bottom red rock of the overlying Catskill No. IX, to which formation of red and grey shale and sandstone he gave a total thickness of only 250′. (General section, R, p. 43). This top limit is seen to fall slowly and almost imperceptibly upon the hill slopes as one ascends the valleys southward; more rapidly in the side vales, according to the rela-

*The highest point is Prospect Hill, 2¼ m. E. of Smethport station. Most of the hill sides of the larger valleys rise more or less steeply from the water to a height of 500 or 600 feet, with broken cliffs of Pocono sandstone, No. X, and sometimes vertical massive cliffs of the Olean conglomerate No. XII. See Ashburner's Report R, 1880, Chapt. 1, with a map of the water basins, and tables of elevation along the dividing ridges. and railroads following the streams. His topographical survey of the county was one of the best pieces of work on the Survey; and a model of the relief of the surface was afterwards made from the contour line map published in the Atlas to R, and is now in the cabinet of the Survey.

tive shortness and steepness of their water channels ; and in all cases disappearing sooner or later in a point under water level.* As only one or two hundred feet of the topmost strata of the Chemung formation present outcrop exposures for examination anywhere in the county, even where the streams have cut their beds into it the deepest, we are wholly indebted to the well records for a knowledge of the formation, which has a thickness of at least 2000′. How much more is not known ; for, of the two wells selected as the best for the purpose, the Dennis well No. 1 near Bradford gives only 1282′ of it down to the top of the Bradford oil sand (54′); and the Smethport well No 1 stops at 644′ beneath the bottom of that sand (1282+55+644=1980).

These are Ashburner's three divisions of Chemung as a whole:—Upper shales and sands; Middle (Bradford) oil sands ; Lower shales and sands.

The Upper Chemung was measured in various wells: 1282 at Bradford, 1280 on Lewis run, 1305 at Smethport, 3290 at Ludlow, 1300 in the Wilcox wells. It is itself subdivisible into: Upper gray shales and sands 350 ; Middle red shales and sands 300 ; Lower grey shales and sands 650.†

*See the large colored map in the Atlas. On this the points of disappearance up stream can be seen by following the narrowing belts of the deepest tint of brown which defines the limits of the Chemung exposure at the present surface. Thus : on the Oswayo the Chemung passes into Potter Co.; on Bells run it remains visible up to Taylors run ; on Kings run it goes up to Glenn P. O.; on the Allegheny river it ascends 14 miles nearly to Port Allegany ; on Potato creek 14 miles to Smethport, and 2 miles further on the main stream, and 6 miles further on its Marvin creek (S. W.) branch to Kasson P. O.; on its Knapps creek (W.) branch to Rixford; on Tuneongwant creek it passes Bradford and ascends (S.) 12 miles to a little beyond Big Shanty; up the West branch it disappears at Collier run ; on Corydon creek (in the N. W. corner of the county) it shows for 8 miles, from the Warren line and for 6 miles up the different branches of Sugar run ; on Kinzua creek it remains visible 18 miles up to the Hulings Oil Well No. 1; and on its south branch 6 miles, disappearing at Swamp Lodge run. In the S. E. corner of McKean the Cameron outcrop appears along the Sinnemahoning.

† East of Smethport and south of Wilcox, the Bradford sand is absent from the series and therefore no distinct measurements can be made of the shaly upper and lower subdivisions.

In the Dennis well record (condensed) the strata present the following aspect (R, p. 73): *

Ashburner's Upper Chemung.

Slate gray,	8	
Sandstone, dark and grey,	45	
Sandstone, fine, and slate,	216	
Sandstone, grey, and slate,	61	=330
Sandstone, *red*,	10	
Slate, dark,	20	
Sandstone and shale, deep *red*,	63	
Slate and sandstone, grey,	201	
Slate and shale, *red*,	14	=308
Sandstone and slate, grey,	36	
Sandstone, grey and yellow, "*first sand*,"	25	
Sandstone and slate, grey,	44	
Slate, grey,	175	
Sandstone, brown,	17	
Slate,	28	
Sandstone, brown and grey, "*second sand*,"	36	
Slate and some sands, grey,	283	=644

The red coloring matter of the middle subdivision increases towards the south and east. The color is duller and deeper than that of the Catskill rocks. The red bands at top are the most constant, and may represent the *Mansfield red beds* of Tioga and Bradford; but they fail in some of the wells, or are so thin and indistinct as to elude the observation of the drillers. The lower gray subdivision resembles the upper. The drillers call it the "*Bradford oil sand group*," and of course they found a "First sand" and a "Second sand" in it, which the old superstition of three necessary sands taught them to expect before reaching a productive "Third sand," no matter at what geological horizon, or in what oil region they might happen to be operating. Such was the predominating influence of the traditions of the first discoveries on Oil creek, where there are

*The full record of this important well is to be found in Chapter CIII, below, and near its close.

indeed three oil sands, but they lie a thousand feet higher in the series than the Bradford sand.

Bradford Oil Sandfield.

The Bradford oil sand proper is 45′ thick in the Dennis well. But throughout the field underlaid by it its average thickness may be assumed at about 45′.* It is so homogenous from top to bottom that only a close examination of the sand pumpings can discover differences of character in the several layers of which it is composed. It is a deposit of gray and white sand about as coarse as the ordinary beach sand of the New Jersey coast, compact, yet loosely cemented. The grains however are angular, and vary but slightly in size, color, and quantity of cementing material which holds them loosely together.

The Bradford field underlaid by this sand deposit, which has held and given out such incredibly great quantity of petroleum, is 12 miles wide and in McKean county 18 miles long, S. 30° W. and N. 30° E. passing over the state line and extending some miles into New York. Its area in Pennsylvania measures between 100 and 110 square miles. So evenly is the oil distributed through the sand, that of the numberless earlier wells drilled to it only 2 per cent. failed to yield oil. In this respect it differs entirely from the Venango and other fields, the sands of which are conglomerates of small pebbles, running in interrupted and narrow streaks, constituting pools or reservoirs from which the great spouting wells once yielded, under a tremendous head of gas, thousands of barrels of oil per day. The Bradford sand on the contrary is so fine and tight and wide spread, that the flow of oil through it is in all directions, but difficult and slow; so that no well yielded more than 50 or 75 barrels a day ; while the great majority of wells

*The Bradford oil sand is now known to vary from 20′ to 80′ in thickness, and even 100′ in some well records, counting in shale layers which break up its mass more or less (Carll's 7th report 1890, p. 135). The whole group, counting in the drillers' so called "First and Second sand" with it, measuring about 700′, Mr. Carll names "The McKean Group," No. 11 of his long section of oil horizons (I 5, p. 135).

have furnished only 5 or 10 barrels a day, but with great regularity and for a long time.†

The Lower Chemung shales, beneath the Bradford sand, have grey sands and slates, at least to a depth of 644 as shown by the *Smethport well No. 1.* At 360 feet below the Bradford sand this well went through a so-called Smethport oil sand (R, 76), which is perhaps the same as the 18′ sand 1718′ down in the *Haskill well* at Smethport, which yielded 2 barrels a day. But 373′ over it this well passed through a 12′ sand which seemed to Mr. Ashburner to be on the horizon of the Bradford sand.

Carll's Elk oil sand group.

The Elk Group of Mr. Carll is the upper part of Ashburner's Lower Chemung shales, described on p. 78 of his Seventh Report, 1891, as 400′ of brown sands. Its area stretches southeast of and parallel to the McKean (Bradford sand) group, and just under the latter, in McKean, Warren and Forest counties. At the Wilcox Gas wells, southern McKean Co., the two gas sands lie 100′ and 200′ beneath the Bradford sands. "In the Kane oil pool productive sand seems to lie still deeper; as it also does in the newly developed oil fields of Highland township, Elk county." (Carll, 1890). The bottom of the 400′ Elk group lies 1700′ beneath the top limit of the Chemung (Carll, p. 136). From this downward no oil or gas has been found.

The Wilcox geyser.

The first great gas well at Wilcox was bored in 1864–5 (Carll's report I4, p. 104, I5, p. 60, 66) and produced also

† The production of this wonderful oil field reached its highest pitch in 1881, during which year it gave to the commercial world 23,000,000 barrels. In 1880, 1881 and 1882 it furnished 5,000,000 barrels more than the entire world's consumption of petroleum. From that time its production steadily fell off to 10,564,000 in 1885; 9,753,000 in 1886; 7,581,000 in 1887; and 5,306,000 in 1888. Nor can it regain its old importance, for its limits are clearly defined, and its area so studded with derricks that there is no room for promising drilling places. In 1886, 413 new wells were drilled (37 of them dry); in 1887, 142 (18 dry); in 1888, 40 (5 dry).—See Mr. J. F. Carll's exhaustive "Seventh Report on the Oil and Gas Fields of Western Pennsylvania for 1887, 1888" (published as Report I5), Chapter 1, page 1, 2, 3.

some oil; other good oil wells were got in 1887 and 1888 chiefly in the Bradford sand. The brown sand 100′ and 200′ beneath it furnished gas under strong pressure, piped to Bradford, Salamanca, Buffalo, etc.*

The St. Mary's well.

The horizon of measurement down to the various oil sands in McKean, Cameron, Elk, Forest and Warren counties is the base of the Olean (Pottsville) Conglomerate No. XII. The difference of depth to which the boring tools have to go before striking the Bradford Sand at various places is caused by the thinning northwestern and thickening southeastward of formations XI (Mauch Chunk), X (Pocono), IX (Catskill) and the upper part of VIII (Che-

*Carll's report I4, 104, and I5 60, 66.—Ashburner's description of the spouting Wilcox No. 1 (Adams) well in his report on McKean Co., R, 1880, pp. 148 to 159, and his detailed paper on it in the Proc. Amer. Philos. Soc., Sept. 21, 1877, Vol. 17, p. 127, are worth careful study. The record, by Mr. Schultz, shows 1785 feet of strata (from the well mouth 1646 A. T. down to 139 below tide level) mostly olive shale and blue sands; but four thick bands of red shale, 137′, 64′, 31′, 31′ thick in the uppermost 415′ of the well; chocolate mica sand (9′) was passed at 889; red shale (6′) at 930; red shale (2′) at 955, the lowest red seen in the well. Heavy fresh water flow at 60; salt water at 400; gas from 726 to 820; "black gas" from 900 downwards; hard, compact siliceous rock at 950; pyrites at 1000; hard sandstone parted by soft slate 21′ thick from 1222 to 1243, *strong gas vein* at the top and less strong from the bottom of it; *gas* at 1230; small red and white pebbles in sandstone (25) at 1250; *strong gas* at 1280; plenty of "soot" at 1480; increasing gas at 1560; strong gas at 1600. In 1877 jets of water were driven into the air every seven minutes to heights of 85 to 115 feet, after the gas veins at 1200 and 1600 feet down were struck; after the fresh water flow was tubed back these ceased. July 19th Mr. Ashburner watched the jets and triangulated their heights; his observations are tabulated on page 153, of his report, and a beautiful diagram of the jets is given on p. 155. His explanation of the *geyser action* is given on p. 156. The estimated pressure of the gas when 175 feet of casing was blown out of the well was about 250 lbs. to the square inch; but he estimated the constant pressure of gas unobstructed by the inflow of water at about 50 lbs.—In 1833 Dr. Hildreth of the Ohio State Survey, published in the Amer. Jour. Science, July, 1833, described similar blow wells in the Ohio river salt region. P. Neff's well near Kenyon College, Knox Co., Ohio, which struck gas 600′ down blew into the air columns of gas and water 120′ high at intervals of one minute. The 60′ derrick was in winter a chimney of ice, up through which the jet when fired made a splendid spectacle.—Dr. Hayden's U. S. G. Report on the Yellowstone geysers makes the Grand spout 200′ every 20 minutes, the Giant 140′ every 3½ hours, the Giantess 250′ every 20 minutes, the Beehive 220′ every 18 minutes. In these geysers steam pressure acts the part of rock gas in the Wilcox well.

mung). The drillers took a fixed depth in the Bradford fields as a rule which worked well. But when they sunk test wells in southern McKean and especially in Elk and Cameron where the sand lies much deeper, they stopped drilling far short of the required depth, and concluded that the sand had run out. Thus at St. Marys in Elk Co. they went through 575′ of XI and X, 335′ of red IX, and 1050′ of Chemung VIII, and stopped at least 250′ short of the depths at which the Bradford sand ought to lie by Ashburner's survey (RR, 1885, p. 156).

The Chemung strata passed through in this St. Mary's well beginning under the great red mass (IX Catskill) are: Blue slate 12; sand 49; blue slate 369; red rock (possibly the Mansfield reds) 25; slate 35; blue slate 220; sand 44; black slate and flint streaks ("shells" in drillers' language) 286; sand 10=1050; total depth of well from derrick floor, 2010; calculated depth of Bradford sand below Olean (XII) 2210 or more; whereas at Bradford the Bradford sand lies but 1770 beneath the Olean. At Tidioute in Venango county, far west of St. Marys and still further southwest of Bradford the depth is almost 2000.*

*See Carll's discussion of the embarrassments of the drillers' calculations caused by their ignorance of the thickening of the interval between the Olean and the Chemung from 570 at Bradford to 765 at Tidioute in Report I5, 1889, p. 77. In a future chapter on the Catskill formation, No. IX, I will show the progressive thickening of X and IX along the line from Bradford southeast to Cameron, a distance of 42 miles; while the Upper Chemung thins in that direction, leaving the B. sand 800 feet lower at Cameron than at Bradford.—But the best exhibition of this phenomenon is made by Ashburner's large sheet of compared well-record columns in Report R, Atlas, Plate XI, in which the red rocks are colored red to show their gradual descent southward from Bradford to Ridgway in Elk Co. Eleven wells are selected along this north and south line as having unusually good records; beginning at the north:—Dennis No. 1, Smethport No. 1, Haskill, Hulings No. 1, Hukill, Wilcox No. 1, Coburn, Wilcox No. 3, Bear creek, Silver creek and Ridgway. The Olean Conglomerate dips gently southward from 2170′ A. T. at the Dennis well, to 1530′ A. T. at the Silver Creek well; but it is drawn horizontally across the top of the plate and the well records adjusted to it to show the *relative descent* of the red rocks in the 36 m. from north to south. Nothing could exhibit more plainly the unwearied patience and scrupulously conscientious mode of investigation of this admirable and lamented geologist.—A similar but still more striking range of vertical columns related to the Olean Conglomerate as a horizontal line at the top is given in the Atlas to his subsequent Report RR, plate V. This line of wells

The Bond farm well (dry) in the center of Cameron Co. was begun about 100′ below the top of the Chemung and stopped at 1607. It gives therefore the whole "McKean series" above the Bradford sand, and the "Elk series" and lower rocks under it; but no trace of an oil sand was found.*

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ranges S. S. E. from Smethport to Driftwood, and the columns are filled out upward to the Olean by hillside sections; thus: Smethport section and well, Norwich section, Keating section, Shippen section, Emporium well and section, Cameron well and section, and Sinnemahoning section. In the last three the bottom of the Catskill was not reached. In the Smethport column the borehole went down through nearly2000′ of Upper and Lower Chemung.

*Record given in RR, p. 11.—Conductor 25; layers of mostly fine sand 200; *red* rock 12; hard "shells" 108; *red* rock 5; "shells" 75; soft slato 175; sand 55; slate and "shells" 295; sand 70; hard "shells" 55; *pebble sand* 4; soft slate 250; "sand shells" and slate 278=1607. The Bradford sand if it existed in Cameron Co. ought to have been passed in this well at 1200 (i. e. 1300 beneath the top of the Chemung.

CHAPTER CI.

The Warren Oil Sands.

The extreme complexity of the Chemung deposits is illustrated by the difficulty of coördinating the rocks which produce oil about Warren with the Bradford sands in McKean Co. on the one side and with the Venango sands on the other side. The Warren sands lie above the Bradford, and beneath the Venango. But no Warren oil has been got in McKean Co. over the Bradford, nor in Venango Co. under the Venango Third sand. All that can be asserted is that the oil-bearing rocks on the Allegheny river at Warren fade away northeastward into the barren Upper Chemung (McKean series). Both in Warren and Forest counties the upper part of the Chemung has well-defined and massive layers of white and gray oil-bearing sandstones, the highest lying about 300′ from its top (the base of the Venango Third Oil Sand) and the lowest about 1200′. In descending series they are known as the

Warren oil sands.
Clarendon oil sands.
Cherry Grove oil sands.
Cooper oil sands.

They all lie embedded in typical Chemung slates or rather shales, which continue to descend beneath the Cooper sands as far as the deepest holes have been put down. Some of these "pools" lie not more than ten miles east of the rich pools of the Venango group, and yet these last fine away and disappear in this interval, so that hardly a trace of them can be detected in the upper part of the Forest county wells. The lower oil sands however can be traced S. W. across Forest and Venango counties for 30 miles; and in eastern Venango the "Speechley sand" has yielded much gas, but no oil. This gas rock underlies the interval between the Venango and Clarion oil belts, a barren strip separating the two belts (Carll's Seventh Report, I5, p. 76).

The Warren oil sand group in some way interlocks in the McKean series above the Bradford sands. It is said by Carll (I5, p. 131) to have so variable a constitution that no defined top or bottom limit can be assigned to it. At north Warren the upper part is shaly, and the largest of its wells were said to flow from these shales; while others flowed from a so-called "Second sand." This "Second sand" is fairly developed at Warren, but the oil generally comes from the "Third sand.' At Stoneham a still lower "Fourth" or Stoneham sand gives the oil; while at Stoneham the north Warren shales are barren sandy measures. On the other hand the Stoneham sand is barren at north Warren. From the top of the north Warren shales to the bottom of the Stoneham sand the group measures about 300′. Between 1880 and 1888 there took place however such an extension of the group downwards that it now measures 900′; i. e. the Warren "Third" sand, the Stoneham-Clarendon "Fourth" sand, the Cherry Grove-Balltown sand, and the Cooper sands; beneath which no other sand beds have been found within the limits of the Warren field. The Cooper sand lies about 1200′ beneath the Venango Third sand, the base of which Mr. Carll makes the top of the Chemung. This 1200′ then consists of an upper Warren sand group, and a lower McKean group (see also Report I4, p. 382).

There remains 300′ more or less from the top of the Warren group up to the base of the Venango Third sand, which Carll makes the top of the Chemung. The interval is uncertain because the Venango sands do not reach northeast so as to overlap the Warren, nor do the Warren sands reach southwest so as to underlap the Venango. These 300± of shales are soft, bluish grey, with some layers of green, purple and red, and some irregular layers of thin blue-gray sand beds.*

* I5, p. 130.—The description of the Warren wells previous to 1883 is to be found in Carll's Report on Warren Co., I4, Chap. IX, p. 209.

Range of Warren Co. oil horizons.

No county in the northwestern quarter of the state has so great a range of oil sands. For the Venango group enters its southern limits; the Hosmer Run wells getting oil from the First sand; the Triumph well spouting vast quantities from the Third sand, here 120′ thick; the Enterprise, Colorado, New London, Fagundus and West Hickory wells being reliable fields for years. The Warren field started in 1875; the Clarendon and Sheffield later; the Cherry Grove in 1882, eclipsing them all, its first ten wells starting off with an average each of them of 2000 bbls. a day.—These horizons are thus measured by Carll (I4, 165) down from the Olean Conglomerate:—Venango First sand (top) 450′; Third sand (bottom) 800′; North Warren *slush oil* 1100′; Warren Third sand 1300′; Clarendon 1450′; Cherry Grove 1625′; Sheffield (Blue Jay) 1850.

The top of the Chemung formation *VIIIg* in Warren county, if that top be assumed (with Carll) at the base of the Venango group, settles slowly upon the hill slopes of the Allegheny river and its branches with a gentle south dip (of less than 1°) and goes under water at various distances from the state line; as may be seen on Carll's colored geological map in I4, and in the Geol. Hand Atlas of the state, X, plate 56. For instance: In the main valley of Allegheny the top of the Chemung goes under at Kinzua P. O.; on the Conewango, at the mouth of Rhind's run; on the Stilwater, at Sugar Grove P. O.; on the Little Brokenstraw, at Lottsville P. O.

But if the Chemung formation be considered (with Stevenson) as including the Venango group, that is, if its upper limit be carried up to the top of the Venango Oil Sand group, then all the principal valleys of the county have their side hills lined with uppermost Chemung outcrops, with only one exception, that is, the valley of the Tionesta from Stoneham down to Sheffield; and this is indicated by the bands of red color designating the Venango group on the map. It is a matter of no account whatever; a mere question of names; deserving of very little consideration;

but very embarrassing to the constructor of the new Geological state map, who finds it next to impossible to color in harmony the two neighboring counties of McKean and Warren, or Warren with Erie and Crawford which border it on the west.

Before going on to Prof. White's section of Chemung in Erie county I will add here the instructive sections of Mr. Carll and Dr. Randall at Warren.

Carll's section at Warren.

Olean Conglomerate, $2\frac{1}{2}$ m. W. of Warren (XII),	77
Mauch Chunk soft measures (XI),	25
Sub-Olean Conglomerate, massive sandstone (X),	30
Shales, with sandy beds, and *Spirifer beds*,	23
Sandstone, hard, fine grained,	5
Concealed,	11
Sandstone, thin, fine, greenish grey,	8
Concealed (soft),	3
Spirifer bed,	3
Concealed (soft),	3
Sandstone, sandy slate, thin, fine micaceous,	9
Concealed (soft),	29
Shales, sandy,	10
Sandstone, thin, fine, greenish grey,	6
Concealed (soft),	20
Sandstone, slaty, thin, fine grained	5
Concealed (soft),	10
Sandstone, slaty, and shale, thin bedded,	5
Concealed (soft),	14
Shales, brownish grey,	2
Concealed (soft),	10
Sandstone, shaly, slaty, reddish grey shales,	11
Shales, olive, very soft,	64
CONGLOMERATE, pea pebbles, red matrix,	20
Sandstone, fine, shale partings,	3
Sandstone, fine, beds 6″ to 1′,	$5\frac{1}{2}$
Sandstone, excellent *building stone*,	2
Sandstone, fine, beds 6″ to 1′,	$6\frac{1}{2}$
Concealed,	54
Sandstone, thin bedded, fine grained,	10
Concealed (sandy shales?),	23
CONGLOMERATE, pea pebbles, *Fish bed*,	1
Concealed (soft),	11
Sandstone,	7
Sandstone good, *quarried*,	9
Sandstone, softer, greyer,	3
Concealed (soft shales?),	56
Sandstone, thin beds, fine grained,	18
Concealed (soft),	14

Shales, olive at base,	16
Sandstone, shaly and shale,	6
Concealed (probably the same),	27
Shales, olive,	3
Sandstone, slaty, thin, fine, olive, hard bands,	11
Shale, *red*,	9
Concealed (*red* shales, etc.),	68
Railroad, P. & E. depot, Warren,	—
Concealed to river bed,	24
Total thickness of rocks in section,	675

Lowest 228′ have a decidedly Chemung character.

*Randall's Section at Warren.**

A. Summit rocks at Great Bend: sandstone massive, yellowish and white, with slate and shales, and thin coal beds, and a bottom massive angular pebble conglomerate (10′); the middle division of the Pottsville Conglomerate, formation No. XII, with Lepidodendron and Sigillaria tree stems; in all 195′.

B, C. *Sharon shale group.* Shales and slates with two thin coal beds; with fossil casts of seaweeds, ferns, Lepidonendron, Sigillaria, a Rhynchonella shell, and Ctenacanthus fish spines; 45′ to 50′.

D, E. *Olean Conglomerate,* lower division of No. XII; sandstone massive, coarse, 15′ to 30′; massive with roundish pebbles, coarsest at the base, 30′ to 40′; Lepidodendron, Sigillaria, Calamites, Stigmaria; a Ctenacanthus fish spine; total 50′ to 60′.

*No man, says Mr. Carll, in Report I4, p. 304, is more thoroughly acquainted than he (Mr. F. A. Randall of Warren) with every rock exposure and every fossil bed in this locality. The items of the section must be carefully considered as purely local. For instance the Fish Conglomerate (N.) cannot be traced as a conspicuous *fish bed* except over a very small area near Warren. At the Asylum quarry, about a mile to the north, another and quite different *fish bed* is seen, and this comes at the bottom of division K. The Conglomerates and even the coal beds are very local.—The fossils collected by Dr. Randall are numbered and catalogued in the State Geological Museum in reference to the numbers of this section. See Catalogue Volume O3, p. 25, from Specimen 9392 to Spec. 9685.—Dr. Randall's section is given here in full, in order to place the Chemung formation in its connection with the higher formations and to show how the Chemung fossils continued to live in the northwest long after they perished in the waters of middle Pennsylvania, and therefore how impossible it is to base our system of formation names and formation limits on a palæontological basis.

F. *Shenango shales* (Mauch Chunk No. XI ?) buff, thin, sandy, upper part siliceous ; 40′ to 50′.

G. *Sub-Olean Conglomerate* ; Pocono No. X ; massive sandstone beds and flat pebble beds (pebbles up to 2″ in the upper layers) graduating downward into loose grained yellowish sandstone beds, current bedded and seamed with iron. Fossils (O3, p. 26, 257), Fucoids, Sigillaria, Crinoids, Cladopora, Fenestella, a radiate undetermined (No. 9448–9449), Streptorhynchus chemungense, Platyceras varians, inequale, mitelliforme, breve, dorsale, striatum, Cyrtina triplicata, Rhynchonella striata, medialis, Stenoschisma eximia, Syringothyris angulata, Leptodesma leiopteroides, lamellosum, Mytilops metella, precedens, Ptychopteria galena. To these names, corrected by Simpson, Randall adds Archæocidaris, Lingula, Strophomena, Productus, Productella, Pleurotomaria, Orthoceras, Nautilus, and Bellerophon, all without specific names.—Total 40′ to 50′.

H. *Pocono sandy shales ;* with the following fossils named by Simpson :—Orthis pennsylvanica, lencosia, Spirifera disjuncta, mesocostalis, Syringothyris randalli, angu lata, Stenoschisma (Rhynchonella) eximia, Athyris spiriferoides, Meristella incerta, Pararca (Edmondia) erecto, venusta, Aviculopecten æqualata, Crenipecten winchelli, Lyriopecten tricostatus, alternatus, Leptodesma leiopteroides. Besides these Randall names : Fucoids, Dictyophyton, Crinoids, Palæochinus, Orthis michelini (which is doubtful), a Grammysia, a Lingula, and a Bellerophon.*—Total thickness, 40′ to 50′.

I. Micaceous slates and slags, with layers of shales, Pocono No. X. Thickness 100′ to 110′.

J. Sandstones, massive, fine, grey, 10′; Shales yellowish brown, 10′; Flagstones, some massive, green and brown, 50′.—Fossils : Plant impressions, Fucoids, Dictyophyton, Crania, Mytilops præcedens, Streptorhynchus chemun-

*Randall remarks (I4, p. 305 foot note) that although there may be many Chemung species among the fossils of Divisions F, G, H, in all about 100 species collected by him, yet the greater portion are undoubtedly of Waverly type (Pocono No. X), and many of them have been specifically identified as such by western geologists, among others *Orthis michelini* and *Rhynchonella missouriensis*.

gense, Spirifera disjuncta, Goniophora curvata, cuneomya, Crenipecten caroli, Lyriopecten fasciatus, Paracyclas erecta, Schizodus chemungensis, Stenoschisma eximium, Ptychopteria proto, Leptodesma. Total thickness, 70′.

K. Shales, yellow brown, with one *Calcareous sandstone* (2′); fossils, an Orthoceras, a Euomphalus, and a new species of Pleurotomaria. Thickness, 50′.

L. Asylum quarry rocks. Sandstone partly flaggy, partly massive, 10′.

M. Shales, dark, weathering brownish, assigned to the *Catskill formation No. IX.* Fossils: Fucoids, Grammysia communis, Leptodesma parallela, Ptychopteria falcata, lata, beecheri, galena, and another new and unnamed species (No. 9622, called by Randall a Yoldia).—Thickness, 10′.

N. *Fish horizon*, a flat pebble Conglomerate of variable character (Catskill No. IX?) in some places massive and pebbly throughout, in others pebbly only at the top and at the bottom, with center beds of flagstone. At Warren the pebbly beds hold many fish remains, among them teeth of a Dipterus, and plates of a large placo-ganoid fish. It has also a large lamellabranch. Thickness, 15′ to 25′.

O. Shales, bluish, with Lingulæ, 20′.

P. Tanner's Hill quarry sandstone, yellowish, partly false bedded; with Fucoids, a Cypricardia, an Orthoceras and a Goniatite. (*First oil sand?*) 14′.

Q. Shales, sandy, bluish; weathering yellow brown, 100′ to 110′; sandstone, flaggy, yellowish, false bedded 10′ to 20′; with Fucoids, and an Orthoceras. Maximum thickness, 130′.

R *a*. Sandstone (*Second Oil Sand?*) massive, green and brown; 15′; shale, mottled olive and red, 2′; sandstone, massive, frequently changing to mica slate, 14′; Fucoids, and a Trilobite. Thickness, 31′.†

R *b*. *Tanner's Hill red shale*, 8′ to 10′.

S. *Chemung shales* (VIII g), blue, with irregular occa-

†These layers are visible at a number of places in and around Warren; always accompanied by underlying *red shale*. Lepidodendra are found in the lower sandstone layers and in the shaly partings of the upper member. Crustaceans, (*Ceratiocaris* ?) were got near the brewery.

sional flag layers, down to river level at Warren; with Productella, Rhynchonella and Fucoids; 91′.

Many specimens of an *Archimedes* and a *Dictyophyton* were picked up at Warren as loose specimens, the horizons of which in the hillside could not be determined.

From M, the shales over the fish horizon, to P, the Tanner's Hill quarry beds, the measures were marked (doubtfully) as Catskill IX; Q and R left undetermined whether they should be considered Catskill or Chemung. There is no certainty that P and R represents at Warren the First and Second Venango Oil sands, nor any sign of the Third sand, if it be above river level. Mr. Ashburner rejected the idea of the Mauch Chunk red shale formation existing in N. W. Pennsylvania, as F of Randall's section. He thought that all the strata from the base of the Olean conglomerate XII downward to M are Pocono, X; and that the Venango oil sand group is Catskill, IX. Stevenson considers the Venango group and even higher rocks, to be included in the Chemung, VIIIg. In a following chapter on the Venango group its great red beds will be described. Carll was disposed to consider this great red deposit as Catskill; and to divide the group between the two formations. This would agree with White's *Passage Beds* (VIII–IX) on the Juniata and North Branch Susquehanna; practically included between the Lackawanna and Allegrippus conglomerates. But there is no *proof* that the conglomerates on the Juniata are identical with any two of the Venango sands. On the contrary it would be strange if they underlay *continuously* so great an area. If the oil sands cannot be found as near by as McKean county how can we expect to find them as far away as Bedford, Huntingdon or Bradford counties?

Before describing the Venango group, I will give in the next chapter White's account of the Chemung rocks in Erie county, although some of it will need explanation by a reference to the chapter on the Venango group.

CHAPTER CII.

VIIIg, Chemung in Erie county.

In Erie county, along the upper slope of the high divide looking down on the south shore of Lake Erie, runs the long outcrop of a series of 325 feet of Chemung rocks, in alternating groups of shale and sandstone beds; some of the sandstones tolerably massive in the upper part of the series; but no pebble rocks nor any coarse sands. Prof. White gives the following generalized section of this series in Report Q4, on Erie and Crawford counties, as lying over his series of *Girard shales* described in Chapter 93 above, and underlying the *Venango Oil Sand Group*, to be described in a future chapter.

General Section in Erie county.

Shales, blue; with thin sandy layers,	25′
Spirifer bed,	1
Sandstone somewhat massive,	15′
Shales,	20′
Sandstone, flaggy,	15′
Sandstone and *spirifer bed,*	12′
Shales, blue,	30′
Spirifer bed,	1
Sandstone, flaggy,	20′
Shales, blue; *fossiliferous,*	50′
Sandstone, flaggy,	20
Shale, blue,	3′
Sandstone, flaggy,	17′
Shale, blue; *fossiliferous,*	10′
Sandstone, flaggy,	10
Alternate shales and sandstones, flaggy,	75′
Limestone impure,	1 = 325′

Fossil shells are wholly wanting at the base of the series; increase in number upwards; and become very abundant through the upper 175′; with numerous *Spirifer beds*, only two of which are specially mentioned in the section given above. The common forms are:—*Rhynchonella contracta,* *Leiorhynchus newberryi*, *Spirifera disjuncta*, *Spirifera mesocostalis?* *Productella hirsuta*, *Productella lachrymosa?* *Productella boydii*. Besides these many other genuine Chemung types (*Atrypa hystrix*, etc.) occur (Q4, 118).

On the Ohio state line, the lower half of the *Chemung strata* cover half of Springfield township and the middle and upper of Conneaut township, spreading southward into Crawford county; but concealed by a thick covering of northern drift, except where the rocks project here and there from the side slopes of Conneaut valley; as, for instance, at the bridge below Cherry Hill, P. O. where blue shales 12′, and sandy flags 4′, contain numerous specimens of *Avicula fragilis?*

In Girard township, at the bridge over the south branch of Elk creek, near Babbit's, the bottom Chemung flag strata are seen:

Sandstone, at the top, ... visible	3′
Shales, *fossiliferous* (*Avicula fragilis*),*	0′ 6″
Sandstone, shaly, ...	15
Shale, blue, ...	20′
Sandstone shaly and blue shales, to creek, ...	15′

In Fairview, the high land along the south township line is capped by the *Third Oil Sand*, under which appear the whole of the *Chemung flag* series, thus:

Ryan's section.

Third Oil Sand (at the quarries), ...	6′
Chemung shales and sandstones, to the bottom limit of fossiliferous beds† (20′ being added for southern dip), . .	270′
Shaly and flaggy sandstone (*totally destitute of fossils*), .	55
Calcareous band, ...	0′ 6″
Girard shales to level of Elk creek, ... visible	50′

McKean township, across which Elk creek cuts its valley from east to west, is two-thirds covered with *Chemung*

*This shale, full of *Avicula fragilis* is the lowest horizon at which Prof. White found any fossils at all; not a trace of any animal being seen in all the fine exposures of the underlying *Girard shale* from this to the mouth of the creek.

†The shells of this series are closely allied to, if not identical with, *Avicula fragilis*. The calcareous band corresponds to one seen in the same position below Howard's quarry, Franklin township.

flags. One of the beds near the base, 1′ to 1½′ thick, is quarried by Mr. Vorse, one mile west from Middleboro.

In Mill Creek township, the lower *Chemung flags* run along the southern line; the upper beds crop out in Summit and Green townships, and extend down the valley of Leboeuf creek through Waterford township into Leboeuf township; but the valley is very wide and covered to a great depth with northern drift.*

In Green township, nearly the whole surface is made of the *Chemung flags*, which are exposed occasionally along the many hillsides. The *Third oil sand* at Nettegan's is 1400′ A. T. with fucoidal sandstone 10′ or 15′ under it.—One mile south from Nettegan's, a blue sandstone (Chemung flag) 2½′ thick, in three layers, is quarried by Appleman, at 1320′ A. T.; and a little farther south by Ripley, at 1310′ A. T. At Crawley's Run bridge, farther south, a blue flaggy sandstone in the water is filled with *Orthis unguiculus*, *Atrypa hystrix*, and many other *Chemung shells*. In the southeastern part of the township, a massive sandstone, bluish-white, appears at Cutlar's at 1400′ A. T.

In Harbor Creek township the surface slowly rises in a broad terrace to 875′ (300′ above lake level); then a slope upward is more rapid to the second terrace, 1070′; the third terrace being 1175′ A.T. The principal part of the steep slope is made by the *Chemung flag outcrop* to within 50′ of its top.

In Northeast township (next the New York state line) the great slope is steeper, and the *Chemung flag* outcrop narrower, and higher above the lake. One section at the south township line is as follows; all the measures being quite fossiliferous :†

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* Two miles west from Waterford a trial boring was started 10′ below the Third oil sand and went down through *Chemung* flags and *Girard* shales into *Portage* flags to a depth of 650′, with some gas and a slight show of oil; top of well, 1260′ A. T.; bottom, 610′ A. T.

† The *Spirifer bed* is very limy where the outcrop has been long exposed to the weather. The bottom blue sandstone is quarried by Lathrop as a fine-grained, very blue, quite fossiliferous building stone; containing *Spirifera disjuncta*, *Rhychonella contracta*, *Leiorhynchus newberryi* and many *seaweeds* also. Probably the same sandstone 5′ thick, in layers from 6″ to 12″, is quarried by Atkins one mile northwest of Lathrop's at 1300′ A. T. and underneath it here are 40′ of bluish-green shales with characteristic *Chemung fossils.*

Switzer's section of Chemung flags (*Q4, 298*).

Sandy shales and thin sandstone (1440′ A. T.), ...	40′
Shale, chocolate colored, ...	15′
Shales, blue, ...	60′
Spirifer bed, ...	1′
Concealed, ...	40′
Sandstone, blue, ...	4′

In Greenfield township, the *Chemung flags* descend the north branch of French creek, and continue along the valley across Venango township, and Amity, into the southeast corner of Waterford; the dip of the rocks being about the same with the fall of the stream for twenty miles; so that the formation might be studied in a hundred places were the surface of the whole country not so over-spread with northern drift.*

From what has been said, and from an inspection of the colored geological county map, it may be readily understood that the *Chemung flag* formation continues exposed (with an exceedingly gentle southerly dip) down the branches of French creek, until its top beds get below water level near Waterford, at the mouth of Leboeuf creek. Still sinking (southward) beneath Crawford and Warren counties, into Mercer and Venango, it gets gradually buried to depths of 1000′ to 2000′ beneath Jefferson and Indiana counties and all the rest of western Pennsylvania; only appearing at the present surface in the gap of the Conemaugh, Loyalhanna, and Youghiogheny rivers. As the formation underlies the *Venango oil sand formation*, with its first, second, and third oil sands, in which the many thousands of oil wells have all stopped, we would know nothing of the *Chemung* throughout the oil regions were it not for borings made to test the country underneath the Third Venango oil sand. These discovered the Warren and Forest oil sands in the Chemung, and the Bradford oil sands of McKean county in the Portage formation; as described elsewhere.

*Near Greenfield postoffice, a trial well commenced at 1400′ A. T. is said to have gone down first through 60′ of drift and then through 720′ of soft blue slate to a great vein of gas and water (Q4, 296).

CHAPTER CIII.

VIII g. Venango Oil Group. Erie Co. outcrop. Panama and Salamanca conglomerates.

Before describing the Chemung formation where it attains its greatest size, in the middle counties of the state, including its debated Passage beds upward into the Catskill, this is the best place for giving a summary of these passage beds, the Venango Oil Sand group in the northwest, and their probable connection with the remarkable Upper Chemung conglomerate at Panama, Salamanca and other places in the extreme western counties of the State of New York.*

Character of the group.

The *Venango Oil Sand formation*, about 300′ thick, consists of three deposits of sand, and two intermediate deposits of shale. The sands were named by the first oil borers on Oil Creek as they descended through them the *First*, the *Second*, and the *Third Oil Sand;* all three locally charged with rock gas and rock oil ; very abundantly at some points ; less at others ; at many points scarcely at all. After thousands of wells had been sunk it was proved that the rock would yield petroleum rapidly and abundantly only where it was a very coarse sand or gravel. It was soon found out that gravel was not a common, much less a universal characteristic of the deposits, but only along lines stretching northeast and southwest. Most of the development was along two belts, only about a mile wide by thirty or forty miles long. At the two edges of a belt the deposit turned from gravel into fine sand, or sandy shale, holding indefinite quantities of oil, but not permitting it to move

*Consult Carll's Reports I, on Venango county, 1875 ; I2, Oil well records, 1877 ; I3, Warren, Clarion and Butler fields, 1880 ; I4, on Warren county, 1883 ; I5, oil and gas regions, 1890. Also his Preliminary report on oil and gas in Annual Report G. S. Pa., 1886, Chap. 1 ; and An. Rt. Part 2, 1887.

rapidly enough toward the bore holes, which were therefore abandoned, as so called dry holes. Even the gravel belt itself was found to be not absolutely continuous as gravel, but in many places turned to fine sand, commercially unproductive ; but only for short distances ; after such intervals the gravel coming in again and yielding large quantities.

Two principal belts of Productive Oil Sand cross the Allegheny river ; called in reference to the Pittsburg market the Upper and Lower belts.

The *upper oil belt* extends from Tidioute, in Warren county, south-southwestward across Venango, nearly to the Butler county line, 42 miles. A number of *pools*, or small productive areas, lie to the right and left of it, quite separate from each other.*

The *lower oil belt* extends from Paint Creek, in Clarion county, southwestward to Foxborough on the river, and thence south-southwestward to Herman, six miles southeast of Butler, 39 miles.

A curious *cross belt*, 12 miles long, runs from the river a little north of Brady's Bend northwestward to Greece in Butler county.

Seven pools occur between the two belts ; one in northwestern Clarion ; one on the north Butler line ; the rest in Venango county. Another important outlier is on Thorn Creek, six miles southwest of Butler ; and others further south.

A vast number of trial borings outside the limits of these belts and pools, have gone through the oil sand formation without success. But in Warren county, Forest county, and McKean county petroleum has been obtained in great abundance from still lower rocks, described elsewhere. In the Venango Oil Sand formation, with which alone we are dealing, the streaks of gravel which hold the Venango oil are a strictly local phenomenon ; and as yet unexplained. The formation itself spreads far and wide under western Pennsylvania and undoubtedly contains vast quantities of oil and gas, considered as a whole, which cannot be obtained by the ordinary method of boring because the rock is every-

*See Map of the Oil Regions and particular description hereafter.

where except along the oil belts of too tight a constitution, with too little gravel and coarse sand and too much clay to allow the gas and oil to move about with any freedom. Many wells were sunk in Crawford and Erie counties, all of them unproductive; but all of them passed through what was evidently the Venango Oil Sand formation; and from many of these wells issued small quantities of gas and shows of oil, but never in sufficient quantity to pay their sinkers. They demonstrated however the continuity of the formation under western Pennsylvania and eastern Ohio.

The Venango formation wide spread.

Before the work of the Geological Survey commenced Mr. Carll had demonstrated to his own satisfaction not only the persistency of the three Venango Oil Sands far beyond the narrow limits of the oil belts proper, but the unique character of the Oil Sand formation itself. During the first years of the survey he completed this demonstration to the satisfaction of all intelligent oil men, and published the proofs in his several reports (I, I2, I3, I4), to which the reader is referred for a world of detailed evidence and explanation. In these reports he shows that the rocks *above* the oil group have a special and very different character, as will be described hereafter; and that the underground *beneath* the oil group has also a special and entirely different character, totally destitute of anything like Oil Sands in the country to the southeast of the lower belt and in the country between the upper belt and Lake Erie. But in the country to the northeast, through which the upper oil belt would pass if prolonged through Warren into McKean county these deeper strata become oil bearing. In other words, the Venango oil formation is underlaid in Warren and McKean and Forest by the Warren oil formation; and that again further northeast in McKean county by the still deeper Bradford oil formation. So that it seems as if a change went on through geological ages in the palæozoic water basin to this effect, viz., that in the Portage age accumulations of seaweed were made on the New York state line; in the Chemung age, further southwest; and in the succeeding age, still further southwest in Venango and Butler counties. The change may have reference to ancient shore lines; but of that we have not succeeded in obtaining any satisfactory proof. In fact we are wholly ignorant of the reason why the Bradford deep oil region does not extend southwestward under the Warren, and why the Warren does not extend further southwestward under the Venango. Taking it in the other direction, we have no explanation whatever of the stopping of the Venango formation *as oil bearing* northeastward into the hills of Warren; nor why the Warren formation holds no oil in its extension northeastward through the hills of northern McKean and southern New York. We only know the facts, that these three great oil formations, produced apparently in the same sea, by the same operations of nature, probably along the general line of the same oceanic or estuary current, do not hold oil over each other, although they were deposited over each other. It may perhaps make the matter still more plain to say that in the First Oil age the coarse sands were deposited only on both sides of the State line; in the next age, the depositing place of the Oil Sand was moved further southwest to the Warren district; and in the Third age it was moved again still further southwest, with the incoming of immense quantities of gravel with the sand, along a belt of country of far greater length, extending in fact into southwestern Pennsylvania. It will be shown hereafter, moreover, that in the Fourth age succeeding the Venango, a still higher gravel was deposited still further southwest, viz., in Butler county, in which oil and gas were locked up in great quantities; viz., the so-called First Butler Oil Sand; and it was about that time, in that Fourth age, that the Berea oil gravel of eastern Ohio was deposited.

The reader must separate distinctly the Venango oil rocks, so-called by the oil men, from the Venango Oil Sand formation of the geology of the State; the first being, as said before, merely a local feature of the second; a feature of enormous commercial importance but not of so great geological significance. Oil men, after hundreds of vain attempts to get oil to the north and south of the oil belts, had no hesitation in asserting that the Oil Sand formation was a narrow strip and nothing more, and that it could not be found anywhere else in the State. But the records of their borings, when carefully examined and put together side by side by the assistant geologists of the State Survey, showed conclusively that the Venango oil formation extended far and wide under the counties of western Pennsylvania as a separate and perfectly distinguishable member of the Palæozoic System. In fact, the surface of the middle counties of the State, east of the Allegheny mountain, showed that it was a universal formation, as really deposited on the Juniata and Susquehanna as on the Allegheny river and Lake Erie. Indeed along the foot of the Allegheny mountain, through Blair, Centre, Clinton, and Lycoming counties, where this Venango formation comes to the surface, it has exhibited here and there slight traces of oil. But the exhaustive work of the Geological Survey has made it equally certain that the formation as a whole is not any more oil bearing than any other formation; and that the vast accumulation of oil and gas along the oil belts in western Pennsylvania is a special and local feature of the deposits, confined to a very restricted, long and narrow region. This is one and perhaps the strongest argument in favor of the theory that the oil and gas were originally produced in the formation itself at the places where it has been in recent years obtained; and against the theory that the oil and gas have been brought up to the oil rocks from the great black formations several thousand feet beneath them, the Marcellus and Genesee. For if the oil and gas were generated down below in those (formations which spread for hundreds of miles in all directions without any serious change of character and exhaled upward to be caught in the Oil Sands and held there, one cannot see why the occurrence of commercial quantities of oil and gas should not be found thus held in sand rocks in every county of western Pennsylvania. The local origin of oil is proved by its local residence.

The Venango rocks towards Lake Erie.

The spread of the Venango oil formation northwestward will be first considered; rising to the surface as it does along the hillsides in Crawford and Erie counties; its lowest or Third Oil Sand cropping out along the summit of the high divide looking down into the great basin of Lake Erie.

The nearest point to Lake Erie at which abundant Venango oil has been obtained is around Titusville, in the southeast corner of Crawford, forty miles in a direct line southeastward from Erie on the Lake. From Titusville toward Erie, scores of unproductive oil wells have passed through the Venango formation with its upper sand strata, blue shale, middle sand strata, dark shale and lower sand; the upper and the middle sands being fine, the lower coarser. They gradually rise northwestward and appear at the surface in the valleys of northern Crawford and Erie counties. The First Sand appears on Muddy creek two miles before reaching Little Cooley, on Woodcock creek six miles before reaching Saegertown, on French creek a mile south of Meadville, and on Conneaut creek a mile south of Dicksonburg. The Third Sand, at the bottom of the formation, does not reach the surface until we get into Erie county at Union City on South French creek, and the mouth of Lebœuf creek, and at Spring postoffice on Conneaut creek. These are the lowest places in the valleys where the Third Sand makes its appearance. From them northwestward toward teh Lake the Third Sand continues slowly to rise along the hillsides on all the headwaters of French creek into Greenfield, Summit, McKean and Franklin townships Erie county. Its outcrop at last looks down from the extreme top of the high land into the basin of Lake Erie, running irregularly along eastward into New York and westward into Ohio. Its final outcrop traverses Elk Creek township and passes up and down both sides of Conneaut creek, and so westward through northern Beaver township into Ohio.

Nothing but the geologically colored county map of Erie and Crawford can explain to the reader the irregular shape of the outcrop belt of the Venango formation; and all that can be said of it in words is that it occupies the highest land between the great valleys descending from the divide southward toward the Allegheny river. By the use of that map, the following description of the formation in Erie and Crawford counties can be easily understood.

For tracing the Venango Oil Sand group southeastward from its Erie county outcrops under the eastern Crawford county hills we may take the valley of Oil creek, beginning at Oil Creek Lake in Bloomfield; level of lake, 1389′ A. T.; surrounded by hummocks of northern drift; hills to the west rising to 1600′ A. T.; hills to the north on the county line, 1700′ A. T.

Of several oil wells sunk around the lake, Dobbins' well at Lakeville station, 9′ above railroad grade, struck Third sand, pebbly, 9 feet thick, at a depth of 384.′*

Venango First Sand in Erie Co.

The First Venango Oil Sand in Erie and Crawford counties is merely a set of sandy shales and flagstones, say 20′ thick more or less, nowhere coarse or pebbly. At Meadville these flags rise out of the bed of French creek and run along the west bank northward, being easily traced by

*Prof. White identifies it by reference to the base of the Corry sandstone, 76′ above mouth of well, equal 451′ above pebble rock; Corry sandstone being identified by Mr. Carll with Third Mountain Sand of Venango county. (Q4, 224).—Tho Oil Creek Lake Lumber and Mining Company's well No. 1, near the saw-mill (mouth 1400′ A. T.) struck 2′ of white sandstone with oil show at 367′ down.—Well No. 2, near the water-tank (mouth 1405′ A. T.) struck 2′ of white sandstone with oil show at 375′. These two records are given by Mr. Carll in I2, page 273.—To illustrate the absence of the Oil Sands in the condition of coarse sandstone or pebble rock holding oil the well on Mrs. Phillips' land, just southwest from Townville in Steuben county, may be cited as a specimen. Although 1200′ deep, no sands of any importance were found except one fine-grained, gray sandstone at 700′ down, which yielded nothing but gas (Q4, 191).—In Troy township, near the Venango line, Armstrong's oil well on Sugar creek (mouth 1260′ A. T.) went through drift 130′; at 340′ struck lubricating oil; at 550′ a little gas and green oil. The Olean conglomerate being in the hill 200′ above the well, these two sands 540′ and 750′ beneath it represent the Venango Second and Third Oil Sands Other wells along Sugar creek tell the same story.—In Oil Creek township, around Titusville, a great number of wells exhibit the Venango Oil Sands and from here down Oil creek and along the great upper oil belt they have been followed continuously.

numerous exposures ; making a fine bluff on the east bank two miles north of Saegertown (seven miles north of Meadville); 20′ of coarse, dark brownish sandstone layers (1′ to 2′ thick in the railroad cuts); continuing to rise higher and higher in the hillsides past Venango to Anderson's quarry, two miles west of Edinboro (outlet of Conneaut creek overlooking the little lake from an elevation of 1425′ A. T.). At this quarry the layers are bluish-white, fine grained, sometimes a perfect mass of casts of seaweeds (Fucoids), smelling of petroleum, and sometimes stained quite black. This is one of many instances in evidence of the origin of petroleum from the organic substances embodied in the rock itself in place. Only 5′ are here quarried ; the bottom layer being coarse grained and falling to pieces on exposure.

Sixteen miles east of this, on the hilltop a mile south of Union City, the same strata (probably) crop out at 1500′ A. T. showing the general rise of stratification eastward along this line, as shown by the Portage along the lake shore.

Ten miles further east, near the Warren county line, Russell's quarry just north of Corry at 1640′ A. T. works a bluish-white sandstone, the seams and crevices of which hold oil, and parts of the quarry rock are stained with it.

The fossil shells collected by Prof. White from this upper horizon of the Venango formation are all good Chemung types :—Productella boydii, Aviculopecten suborbicularis, Spirifera disjuncta, and a species of Pteronites.

Hosmer Conglomerate in Warren Co.

The First Oil Sand (Hosmer conglomerate)* appears at the surface on Hosmer run, in Spring Creek township, Warren county, west of Garland, just below the old saw-mill ; top, 1430′ A. T.; 15′ or more in thickness ; flat ; largest pebbles (lying in the upper part of the rock) about an inch in diameter, but most of them no larger than millet or mustard

* Compare Cotter Farm conglomerate, in Pittsfield township, to the north; also Wrightsville conglomerate, Freehold township; also heavy oil sandstones in several wells in Eldred township, to the south. But the Cotter Farm conglomerate is at 1455′, two and one-half miles distant, which would make a very flat dip (I4, 254).

seed; white and yellow, with a rather unusual percentage of red and pink; well preserved Spirifera disjuncta, a Rhynchonella, and a smooth cast of an obscure Cypricardia (?) *

Venango Upper Shales in Erie Co.

These blue shales, between the First and Second Sands, in the neighborhood of a hundred feet thick, underly the First Sand along all the hillsides of Erie county; showing occasional thin, sandy layers, which here and there thicken up into sandy flags. Fossil shells are quite abundant at most of the places where these shales come to the surface; the prevailing forms being distinctly Chemung.

Venango Second Oil Sand in Erie Co.

The Second sand makes very little show in Erie county; in fact, can only be recognized by the somewhat increased number of sandy shales or flagstone layers in the whole

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*The exposure is accidental at a point of hill close above water level; looks like a mass slipped down, but is undoubtedly an outcrop traceable by a well-defined bench, above which not a block of sandstone can be found to the hilltop 300′ above. Higher up the creek it furnished oil to the old Hosmer run aboriginal oil pits.—Some prehistoric race has left here and at many places on Oil creek and French creek these relics of their energy. In fact their intelligent acquaintance with every exhibition of oil in the country at the surface is manifested on every stream and at every spring in the region by such oil pits. Twenty-five of these may be counted in the little valley of Hosmer run, but they are fast becoming obliterated. They were dug upon the flats where the stream wanders from side to side. Obstructions of fallen trees, against which the drift-wood piles up and makes temporary dams, cause partial overflows of the bottoms during periodical freshets. New channels are cut; old excavations filled up; the face of the valley constantly changes. Some of the pits were partially opened a number of years ago and reported to be about 8′ square and from 10′ to 12′ deep; with a well-preserved crib work of timbers at the bottom. The oil seeped in from the sides, coming from the neighboring outcrops concealed by the soil. Mistaking its origin the oil men bored from 200′ to 700′ down from the valley bottom, and of course found no oil except what came into the conductor hole near water level (I4, 251).—The Zuver well (1475′) was started 45′ above the Hosmer conglomerate and found it 28′ thick, about one-third of it coarse pebbles; and under it for 525′ soft drillings and no well-defined sand strata.—The so-called Deep well (at 1483′) was 1061′ deep and had the same experience; but the driller remembers a flinty sandstone 15′ thick, pierced at about 800′ down; and a good deal of red rock in the well.—Well No. 3, not far from the Zuver well and starting 130′ above it, found white sandstone 30′ (Hosmer conglomerate), and a pebble rock 228′ beneath it (I4, 253).

mass of softer shales. But its presence as an extra sandy horizon is often indicated by the shape of the ground, by some sort of projecting terrace however indistinct, and occasionally by steeper exposures along the valley sides; but no sandstone mass can be reported, nor even a layer of pebbles, anywhere.*

Venango lower shales in Erie Co.

The Venango lower shales, 100′ to 125′ thick, lying between the Second and Third Oil Sands, are blue, gray, and brown, the whole interval wearing everywhere along its outcrop a much darker aspect than the outcrop of the upper shales.—It is very fossiliferous. Rhychonella contracta, Streptorhynchus chemungense, Leiorhynchus mesocostalis, Productella boydii, Spirifera disjuncta, and many other distinctively Chemung types not specifically identified, lie scattered through the whole mass of shales.

Two Spirifer beds, two special layers of rock crowded with specimens of Spirifera disjuncta, are noticeable in some localities. They are less than a foot thick. They are worthy of especial notice as they furnish a remarkable explanation of a phenomenon which will excite the attention of any local geologist of Crawford, Mercer, Lawrence, and Beaver counties, viz. an immense number of soft rotten flaggish boulders filled with casts of fossil shells which are scattered over the surface of the country all the way to the Ohio river, and are also seen to be mixed with the overcoat of Northern Drift which extends that far. They are fragments from the outcrops of these Spirifer beds carried southward by the ice and also by the general drainage

* Comer's quarry, however, in Washington township, 1355′ A. T., exposed 12′ of bluish-white sandstone (in one and two foot layers), the upper half shaly, the lower half quite solid, smelling strongly of petroleum, which floats off on the water of the springs issuing from its base; and lying on blue shales. The same flags show in the Maynard's run bluffs of Amity township (near the southwest corner of New York) 120′ above the Third sand which is here in the bed of the stream.—Red shale is seen at various places in Erie county somewhere near this Second Sand horizon; for instance, just south of Doolittle's quarry Amity township 15′ of red shale in the roadside 120′ above the quarry rock (Third Sand); and again in the Oil Creek Lake bore hole 166′ above the supposed Third sand.

waters of the district. The rock is as hard as flint; but after being long exposed to the air, and its fossil shells have been dissolved out, nothing is left but the soft earthy, darkened matrix which enclosed them. This decomposition along the present outcrop of the beds is seen in many places to have taken effect to the depth of a foot; and many of the scattered blocks retain a core of the hard undecomposed rock.

Venango Third Oil Sand in Erie Co.; Leboeuf Conglomerate; Carroll Sandstone; Panama Conglomerate.

The Third Oil Sand at the bottom of the formation may be called the *Leboeuf conglomerate* because of its pebbly character at the quarries on Leboeuf creek.* It might

* While we are astonished at the appearance of felspar and other metamorphic pebbles in the Leboeuf conglomerate, as described by Prof. White in Erie county, which must have come from Canada or some equivalent exposed azoic land surface, we are still more astonished at finding a similar peculiar conglomerate with northern pebbles a hundred miles further south, and lying about the same depth beneath the base of the great conglomerate at the base of the coal measures. In the magnificent section of about 1300′ exposed in the gap of the Conemaugh through Chestnut Ridge, between Bolivar and Blairsville, the conglomerate makes the highest arch at the top of the mountain. Under it is the Pottsville red shale formation No. XI. Under this is an arch of Pocono sandstone No. X. The bottom of the gorge exhibits arched strata, referred by Prof. Stevenson to the Chemung No. VIII, 500′ of which are visible above water. The greater part of this column of 500 consists of shale and shaly sandstone in equal proportion and alternating layers; the sandstones exceedingly micaceous and, in fact, little else than compact micaceous mud, reddish-brown to reddish-gray, mostly concretionary and weathering readily; the surfaces of the harder layers covered by a close mat of seaweed impressions; and fossil shells of Chemung type being distributed through the whole section. Near the middle of the section is the curious Conglomerate referred to, 10′ to 20′ thick, so persistent as to appear in the gaps of the Conemaugh and also in the gaps of the Youghiogheny many miles distant further south. The pebbles are not flattened like those in the Pocono sandstone higher up, and are larger than in any of the conglomerates of that region; all rudely oval, thoroughly rounded and polished by long rolling in water; most of the larger ones quartz; but mixed with vast numbers of felsite-porphyry, quite soft, and blackened as if by exposure before being embedded, and pronounced by the United States Geologist Clarence King to resemble the mother rock in Canada. (J. J. Stevenson, Report K3, page 59.) The depth of this stratum beneath No. 12 conglomerate is less than 1000 ; and therefore more than the distance of the Leboeuf conglomerate beneath the great conglomerate; but the difference may well be due to the normal increase in thickness of all the formations southeastward.

be called the *Carroll sandstone* from its fine exposure at the Carroll quarries, at the mouth of Leboeuf creek. Its identity with the *Third Oil Sand of Venango county*, was questioned by Mr. Carll in his earlier reports, but accepted as "positively identified" in his Report I4, p. 177. It might be called the *Panama conglomerate* of Lake Chautauqua in western New York, with which both Mr Carll and Prof. White have identified it by actual observation along its irregular outcrop facing Lake Erie.†

Its outcrops look out from the hillsides of the north branch of French creek and Leboeuf creek to their junction in Le Boeuf township, Erie county; encircle the heads of Elk creek and the valley of Black run; and inclose Conneaut creek for four miles above and below Spring postoffice. Its most northern outcrop projects to the north line of Greenfield; and its Greenfield outcrop runs over the New York State line and continues toward Panama.

Quarries of Erie County.

It is the principal quarry rock of Erie county; its lower layers yielding excellent building stone nearly everywhere. From Leboeuf creek northward, some of its layers are a coarse conglomerate, with the peculiarity that many of its pebbles are of metamorphic rock, and therefore have come a great distance either from Canada, northern New York, or New England; but from Leboeuf westward into Ohio no conglomerate layers are to be seen; they are all sandstones.

Every exposure shows that the rock, whether sandstone or conglomerate, is charged with petroleum.

It is divided into upper gravel beds and lower sandstone beds at so many places that this arrangement of the materials in it may be considered a general one and has an important meaning; for the absence of pebbles toward the west is due to the absence of the upper layers rather than to a general change in the composition. From Leboeuf east-

† The supposed difficulty of identifying the Panama conglomerate and the Venango Third Oil Sand along the Little Brokenstraw valley in Warren county will be discussed further on. Its connection with the Third Sand was made by studying the records of wells from Titusville northwestward.

ward the pebbles increase in number until at Panama, six miles before reaching Lake Chautauqua, it is an immense pebble rock 70′ thick.—A specimen section may be taken at the Carroll quarries at the mouth of Leboeuf creek.

Carroll quarries section.

Shales, ...	6′
Spirifer bed, ...	1′
Shales, ...	8′=15′
Pebble rock (1220 A. T.), ...	7′
Sandstone, bluish-white, ...	8′=15′
Shales, blue to level of French Creek, ...	15′

Here the upper gravel rock is a mere mass of quartz pebbles, mostly flat, that is, broader and longer than thick; with smooth, rounded edges; quartz mostly white, but green and dark jasper pebbles occur, and occasional pieces of felspar frequently fossil shells, also plant fragments.

The lower rock is tolerably fine-grained, of a peculiar bluish-gray or whitish color, not only here, but everywhere throughout the county; in layers from 6″ to 24″ thick, splitting and dressing easily to a beautiful building stone.—No constant plane of division exists between the gravel rock and sand rock; the gravel rock thickening where the sand layers thin, and vice versa. Petroleum is more abundant in the gravel than in the sand, and quarrymen say that they occasionally collect a gallon of heavy oil at a time from the crevices at its base, always enough to grease their wagon wheels.

Doolittle's quarry, 6 m. N. E. of Carroll's.

Sandstone, flinty, hard, fossiliferous, ...	2′
Pebbly layer, ...	3′
Sandstone, bluish-gray, reported (by boring), ...	15′=20′

The top rock is almost a chert crowded with Rhynchonella contracta, Streptorhynchus chemungense, Grammysia hannibalensis, and many other forms so abundant that the layer often becomes a kind of limestone. The top of this layer is covered with a seaweed resembling the *Fucoides caudagalli*. The pebble rock is a mere mass of flat pebbles of white, green, dark, and mottled quartz, cemented in a matrix of very coarse greenish sand. One chunk of felspar as large as a man's fist was seen in it.

The bottom quarry rock resembles that at the Carroll quarries and smells strongly of petroleum.

Allen's quarry, 2½ m. down the run.

Flinty sandstone,*		2′
Shale,		2′
Pebble rock,		2′ 6″
Flaggy sandstone,		5′
Blue shale,		7′
Quarry rock	Sandstone, 1′; Blue shale, 0′ 6″; Sandstone, 1″	2′ 6″=21′
Blue shales,		visible= 5′

At Smith's farm three miles north of Doolittle's, on the Amity township line, we have no quarry rock, but an immense gravel bed or pebble rock 20′ thick, pervaded with petroleum which floats off on the water issuing from its base, a rill of cascades exposing the entire outcrop which forms a cliff around the hill and has dropped huge blocks which now lie scattered over the field below. Base of stratum, 1375′ A. T.; fall toward Doolittle's quarry, 22′ per mile S. 10° W. Blue shales with Fucoids underlie the pebble rock.—At Bailey's, two and a half miles northeast from Smith's, near the New York State corner, the pebble rock in its turn is thinned to almost nothing, thus:—Pebble rock, 6″; shales, 2′; sandstone, 6″; shale 2′; sandstone visible in run, 1′.

Ascending Lebœuf creek to its head in Summit township, and within eight miles of the city of Erie, the rock rises to 1310′ A. T. at Reynolds' quarry, one and one-half miles west of Jackson railroad station, where work has been carried on for a long time. Here 2′ of a fucoidal sandstone is visible; under it blue shale, 8′; under which lies the quarry rock, a bluish-white sandstone, 6′ thick.

* This top layer is Doolittle's top chert layer, being in fact almost all chert. The pebble rock is here a perfect mass of flat quartz pebbles in a coarse mud-colored sand matrix, saturated with petroleum. The two quarry layers are bluish-white rather hard excellent building stone, not affected by the weather. Fall of stratum from 1355′ here to 1320′ at Doolittle's.

Third Oil Sand fucoidal.

From here westward into Ohio, the *fucoidal sandstone* becomes a constant feature, usually overlying but sometimes also underlying the quarry rock; and oil springs issuing from the base of the fucoidal sandstone; parts of the quarry rock itself being often rejected because *saturated with petroleum.* For example:—At Middleboro appear on a little run descending from the south: Fucoidal sandstone, 7′; shales and flags, 12′; bluish-gray sandstone quarried, 7′ (1205′ A. T.). Here vertical fucoidal stems give the upper sandstone a very rough aspect; but some of them lie horizontal. They occur also in the lower sandstone which seems to be completely satuated with petroleum, pools of which follow the base of the outcrop.

Howard's quarry, at Stone Quarry village in the northwest corner of Franklin township, has been long and extensively wrought and shows the following section in which two fucoidal sandstones occur, thus:

Sandstone, hard, rough, *fucoidal*,	5′
Shales and flags,	10′
Sandstone quarry rock,*	4′
Shales,	10′
Sandstone, hard, rough, *fucoidal* (1150′ A. T.),	8′

* Here the quarry rock is like that beneath the pebble rock at the Carroll and other quarries, and in many of its portions is filled with petroleum. Fossil shells are so abundant that portions of the stratum are calcareous and hard as flint; the species (determined by Mr. Whitfield and Prof. Stevenson) being Productella (species doubtful), Chonetes illinoisensis, Streptorhyuchus chemungense, Rhychonella contracta (Stenochysma contractum, Hall), Edmondia burlingtonensis (White and Whitfield), Grammysia hannibalensis (Shumard), Aviculopecten (species undetermined), Pteronites (species undetermined), Goniophora aeola (Hall and Whitfield), Goniophora rigida (White and Whitfield), Platyceras paralium (White and Whitfield), an Orthoceras and a Bellerophon.—The two species of Goniophora and the Platyceras are species of the Burlington group in Iowa, and it is interesting to find them here in northwestern Pennsylvania. As for the whole group of fossils named in the text Mr. Whitfield remarks that they "represent a horizon well down in the Chemung, so that if they be not Chemung then there is no Chemung anywhere."—Fucoid casts also are numerous in the quarry rocks. Many in the upper and lower sandstones have their stems vertical and some of them seem to have a horse-shoe shape, or to enter the top of the rock somewhat like a staple driven into a piece of wood.—Shells filled with petroleum have been found in the quarry rock, some of them when broken letting out a spoonful or more of pure oil.

At Goodman's quarry, northeast from Howard's, are seen the upper fucoidal flinty sandstone, 10′; shales, 12′; bluish-gray quarry sandstone, 8′; shales, 10′; lower fucoidal flinty sandstone, 8′; total, 48′; upper and lower fucoidal sandstones exactly alike ; vertical stems in both ; quarry rock containing petroleum.

Near Spring village, on Conneaut creek, is the only outcrop seen in Crawford county. Here 20′ of sandstone, flaggy above and rather massive below, of a peculiar, bluish-gray color, tolerably fine-grained, base 805′ A. T., overlies very blue soft fine-grained shales holding some iron balls, multitudes of Fucoids, but no other fossil forms.

Slope of the Third Sand up into N. Y.

The rise of the Third Oil Sand eastward toward the northeast and east may be shown by the following table of elevations and distances from Spring village in northwestern Crawford county in the various quarries before described in Erie county, thus :

	Miles.	*Rise.*	*Rate.*
Spring Village to Howard quarry (N. 32° E.), . .	13	265′	20′
Spring Village to Reynolds quarry (N. 34° E.), . .	23	425′	18½′
Spring Village to Middleboro quarry (N. 46° E.), . .	18	320′	18′
Spring Village to Carroll quarries (N. 70° E.), . . .	22	320′	14½′
Stone quarry to Reynolds quarry (N. 66° E.), . .	11	160′	15½′
Stone quarry to Middleboro quarry (N. 78° E.), .	7	55′	8′

This shows a fixed law of maximum rise, say, north northeast. Following the outcrop through western New York by Clymer and Panama, where it caps the high land south of Chautauqua Lake, we get an addition to the table, thus :

	Miles.	*Rise.*	*Rate.*
Carroll quarry to Panama (N. 28° E.), ...	35	530′	15′

At Panama, the base of the 69′ conglomerate is 1750′ A. T. Forty miles further in the same east northeast direction, at Salamanca, a great conglomerate caps the highest land at 2190′ A. T. If this be the Panama conglomerate the rate of rise will be 11′ per mile.*

*Mr. Carll, in 1875, followed the Panama conglomerate outcrop southwestward and identified it to his own satisfaction with the Leboeuf conglomerate at the Carroll quarries. In 1879, Prof. White followed the Leboeuf

Petroleum in Third Sand in Erie Co.

The frequent exhibitions of petroleum on spring water along the outcrop of this rock across Erie county induced for years expensive borings below the outcrop to the extent of probably half a million of dollars. Oil men found it impossible to shake off the traditional superstition that oil springs at the present surface necessarily have a deep source in the underground, even in cases where it is evident to every unprejudiced observer that the oil issues from the rock which shows at the surface. Nevertheless these expensive and fruitless bore holes were of great value for demonstrating the fact that no oil exists in the Chemung formation underneath the Third Oil Sand or Leboeuf conglomerate down to lake level and far below. The quantity of oil held originally in the rock must have been greater than the amount at present residing in it, so much evaporation has gone on through ages. What oil remains since the escape of the more volatile parts in the form of gas, is always a high gravity partly oxidized lubricating oil. Most of what remains resides permanently in the rock, which is in other words soaked with it. The proof of the origin of the oil in the rock itself from the decomposition of seaweeds and the soft tissues of shell fish cannot be resisted. The conversion of the seaweed into petroleum and of water plants into cannel coal has been discussed and demonstrated by Dr. Lesquereux in his reports. But in these quarries of Erie county Prof. White thinks he obtains sufficient evidence of the conversion of air-breathing land plants into oil. For instance, at a quarry on Mr. Canty's land just above the Carroll quarries, in a massive pebble rock

conglomerate outcrop from the Carroll quarry northeastward and identified it with the Panama conglomerate. Carll (Report III, 1880, pp. 58 and 69) determined the top of the conglomerate at Panama by spirit level from the Grant railroad station grade (1437′) to be 1671′.—North of Blockville and west of the lake, 1660′.—Ellery Center east of the lake, fragments on hill-tops, 1750′.—Williams quarry, four miles north of Panama, lower beds? base 1660′.—Lewis' quarry, half mile west of last.—Chautauqua quarry, near Panama station, five miles west of Panama quarry, sand rock under conglomerate base, 1600′.—Bleakley quarry, three miles south of Wattsburg, Erie county (in bore hole) base 1340′.—Beaver run, west side, blocks—Doolittle quarry, three miles west of Bleaksley, base 1330′ (here a well yields a little oil between 42′ and 130′).—Old quarries in Waterford reported by Hodge in 1837.—Carroll quarries, near Leboeuf, base of pebble rocks, 1220 A. T.

completely saturated with oil lie fragments of trees stretched in all directions like a fallen forest or like a matted natural river raft. The woody fiber has not been replaced by mineral matter. The tree trunks have disappeared leaving cavities or moulds of their forms in the rock, and these moulds are now occupied by a soft rotten somewhat cellular substance with a strong odor and the general appearance in parts of the residuum from evaporated and oxidized petroleum. On some of the specimens may be noticed a thin film of coal ; but in most cases the wood itself looks as if it had been converted into oil. These plants may have had soft parts with a structure analogous to the cellular tissue of seaweed, which when changed to petroleum would saturate what woody fiber may have also gone to the construction of the tree. Many such deposits of drifted land plants accumulated at one place may exist, but this is the only instance observed in Erie county. It suggests however such vast accumulations of overturned trees as have been observed and reported by many geologists in their studies of the coal beds ; for instance, the well-known instance at Ashland in the western middle anthracite coal field.*

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* To test the likelihood of the ascensional theory of the genesis of petroleum Prof. White made a special study of every stratum exposed from the Howard quarry downward. A brook makes a cascade 60′ high over the Third Oil Sand and then descends to Elk creek at the rate of 150′ per mile ; Elk creek exhibiting continuous perfect exposures the rest of the distance down to Lake Erie. In 700′ of strata thus exposed to minute examination, he could not detect a single bituminous layer large or small ; not even in the coarse flagstones which occur at intervals in the series was a trace of oil to be recognized. The horizontality, the absence of faults, slides, fissures, or crushes of any kind, and the numerous alternations of impervious clay strata exhibited in this section of 700′ make the ascent of petroleum from below upward to the Third Oil Sand simply a physical impossibility. In confirmation it may be added that 500′ additional (beneath the 700′) have been pierced by wells at the mouth of Elk creek through nothing but the same gray shales and without finding a trace of petroleum or bitumen. At the New York state line 1000′ of such strata underlying the Leboeuf conglomerate are exposed, but no bituminous shales appear among them. Some of the thin sand layers of the Portage formation are indeed more or less saturated with oil in many places ; but that the oil is indigenous to them, that is, has been generated in them originally, is plainly shown by its absence from layers above them and below them which resemble them in all other particulars (White, Q4, 116).

The Panama conglomerate of New York.

Panama conglomerate, so-named from its best exposure in the village of Panama, Chautauqua county, New York, has a considerable range of exposures northeast and southwest from that place. At right angles to this range of outcrop, that is, southeastward into Pennsylvania, it dips and passes underground, rapidly losing its thickness and its pebbly character, becoming at last a merely well-pronounced horizon of sandy shales in the oil wells. It was formerly confounded with the Pottsville conglomerate at the base of the coal measures, the bottom division of which has received several local names: Sharon conglomerate in Mercer county, Garland conglomerate in Warren county and Olean conglomerate in McKean county; the last name being adopted finally in the reports of the State Survey. It will be shown hereafter that underneath the Olean Conglomerate, with its round pebbles, lies another called variously the Chenango conglomerate, the Sub-Garland, and in the more recent reports, the Sub-Olean, with its flat pebbles. The Panama conglomerate is now known to have nothing to do with either the Olean or the Sub-Olean conglomerates, but underlies them by several hundred feet. Its distance beneath them, however, is still in discussion. Prof. White, identifying the Panama conglomerate with the Lebœuf conglomerate in Erie county, and that again with the Venango Third Oil Sand, calculates the distance upward from it to the Olean conglomerate to be 750′. Mr. Carll, although identifying the Panama and Leboeuf conglomerates, could not at first consider its identification with the Third Oil Sand satisfactory, inasmuch as his calculations make it lie only at about half that depth beneath the Olean; so that it would have rather corresponded to the First Oil Sand than to the Third. The importance of the question is so great that Mr. Carll's data are given in the plainest manner possible in a special chapter VII, in Report I4, page 195. His description is to be found in chapter VI of Report I3, page 57, as follows:

The Panama conglomerate makes a north and south ridge at Panama, west of Little Broken-Straw creek, a small branch of which cuts through it making a gorge half a mile long, with an inconsiderable waterfall at the head over 69′ of pebble sandstone in two leaps with a sloping cascade between them, the gorge below being obstructed by huge blocks fallen from the vertical walls, a most picturesque spot. The gorge has been made by the stream undercutting the pebble rock in bluish-green iron-stained clay shales, 25′ of which are exposed, and under them 25′ more containing several layers crowded with fossils.

The Panama rock itself is a mass of quartz pebbles, in a matrix of sand; but the proportion of sand to pebbles is much greater than in the upper conglomerates of northwestern Pennsylvania; and the pebbles, whether large or small, are almost all of them flat or lens-shaped, seldom measuring an inch in their longest diameter, but occasionally even two inches; commonly pure white quartz; some pink, frequently red or slate-colored jasper. The round pebble is as exceptional in this Panama conglomerate as a flat pebble is in the Olean conglomerate; and this is a matter of first importance, inasmuch as we now know that the Olean and all the conglomerates of the coal measures from that upward have round pebbles; while the Sub-Olean and all the conglomerates below that have flat pebbles.

The Panama conglomerate is made from top to bottom of alternate layers of sandstone and conglomerate, blending one with the other according to the proportions of sand and pebbles; a pebble layer of one course frequently running for rods along the face of the cliff; the pebbles lying on their flat surfaces and projecting because the sand above and below the pebble has been weathered back; their projecting edges glistening in the sunlight like a string of beads suspended in front of the cliff. In some cases two or three courses of pebbles in immediate contact have been deposited between purely sandy layers a foot or more thick; and blocks with this structure falling from the cliff split open along the plane of pebbles, exposing two surfaces beautifully inlaid with pebbles. Long ranges of rock have broken off in lines of cleavage (running north 60° west) and sinking a little have settled one after the other away from the body of the cliff, leaving series of fissures from 2′ to 10′ wide and about 40′ apart. These detached masses waiting for their time to fall into the gorge below are traversed crosswise by a secondary series of crevices. Thus the front edge of the formation is split up into vast blocks 70′ or 80′ long, 40′ deep, and 70′ high. Some have already slipped down, rolled over, and lie in the bed of the stream 50′ beneath. This is one of the so-called *rock cities* of southern New York and northwestern Pennsylvania. All of them are constructed in a similar manner. The Olean and Sub-Olean conglomerates exhibit the same phenomenon. The agents are undoubtedly frost and rain, but the forward movement of the great blocks on the slippery clays beneath must be at least assisted, if not entirely produced, by the earthquakes which from time to time, at intervals of years, cause and have caused vibrations in the American continent through all ages.*

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*The first exposure northeast of Panama, on Stony Ridge, mile and a half north of Blockville and two miles northwest of Ashville, shows masses of pebbles loosely held and easily frosted out from the sandy matrix; but some of the layers afford a beautiful white and brownish-gray sandstone suitable for monumental bases, lintels, etc. Thickness, hardly less than 50′. Assumed base, 1660′. East of Chautauqua lake, ten miles north-northeast of Panama, loose pieces lie on the highest hills around Ellery Center at 1750′; while, curiously enough, erratic boulders of Canadian gneiss are thickly strewn over the hill slopes facing the north up to within 50′ of the hilltops. No sign of the Panama conglomerate can be seen in the country to the east or northeast of this for forty miles until we reach Salamanca; the whole country having been eroded down beneath the level of the rock, the whole of which has ueen carried off. It is of course impossible to tell how far toward Canada this deposit originally extended. As a pebble rock it may have been local; but as a sand or sandy shale formation it may have extended into Canada.—Williams' quarry, four miles north of Panama, worked for more than fifty years, furnishing stone for the Mayville court house, a fine grained free working gray sandstone, splitting smoothly and easily, readily wrought into fence posts and square blocks of almost any desired length, seemingly the bottom layers of the Panama conglomerate. The upper surface, covered by a few feet of surface clay, shows glacial scratches running north and south. Base of quarry 1660′. Up the hill 30′ or 40′ higher, a pebble rock is seen precisely similar to that of Panama —Lewis' quarry, half a mile west of Williams', and others in the vicinity show the same.—Chautauqua quarry, near the Panama railroad station, five miles west of Panama, furnishes a fine grained compact bluish-bluff sandstone, con-

It is no wonder that so refractory a deposit should make a strong mark on the topography of the region ; in fact it produces the high range of hills facing Lake Erie. If the deposits had been everywhere as thick, massive, and pebbly as at Panama, without any variations, this range of hills would have been a continuous ridge with a steep slope toward the lake and a long gently descending back country toward the south. But we see the range broken by the north branch of French creek which heads within five miles of Chautauqua Lake. These features must be considered a proof that the deposit loses its thickness or massiveness along that part of its course. Every irregularity in the direction and elevation of the high divide throughout Erie county must stand evidence of similar variations in the deposit ; erosion necessarily acting more efficiently wherever along the line of outcrop the rock thins or becomes more sandy ; and while the general westward descent of all the formations lowers the divide gradually toward the level of the lake, the disappearance of the pebbles from the forma-

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taining minute finely disseminated specks of iron; dresses smoothly; weathers without discoloration and is very durable. The quarry rock is twelve feet thick lying on blue clay shale. On the quarry rock lie thin layers of flat pebbles loosely held in a sandy matrix and iron-stained. The dip, strong to N. N. E. may be local; or may indicate a gentle anticlinal to the south. Base of quarry about 1600′.—Upton's quarry, on Dutch hill, two miles N. N. E., from Clymer, New York, and three and one-quarter miles north of the State line (nine miles N. N. E. from Corry) is the next best exposure of Panama conglomerate, six and one-quarter miles W. S. W. from Panama; top of rock, 1580′. A brook makes a series of little cascades here over 20′ of bluish-gray, gray and yellowish, massive, irregularly bedded, fine grained sandstone, in layers from 6″ to 48″ thick; with wave marks, mud cracks, worm burrows, and seaweed casts abounding on their surfaces; but no fossil shells. The current bedding slopes northwestward. In an elbow of the brook appears an iron-stained conglomerate of loosely cemented pebbles 10′ thick, corresponding in level to the upper beds of the sandstone in which not a pebble can be seen, while the conglomerate is nothing but a mass of pebbles. This interesting locality exibits in a most striking manner the method of deposition called false bedding, oblique bedding, or current bedding, and the various succession of deposit erosion and deposit following each other as the materials were brought in by the current. The sand rock must have been first deposited with a false bedding dipping northwestward, and then the mass of pebbles was thrown down in a wedge shape overlapping. The brook has cut down along the division plane exposing the sand rock on the one hand and the gravel rock on the other (I4, 201).

tion west of Leboeuf creek, and the change of some of its sandy strata into shales, impairs its resistance to erosion more and more and carries the outcrop further and further southward away from the lake.

Connection of Panama and Salamanca conglomerates.

If this be so where we can see it from Panama westward into Ohio we have a right to argue that it is so from Panama eastward toward Salamanca ; and that had the deposit been as thick and pebbly in that direction it would have resisted the general erosion and produced a continuous high ridge or range of hills from Panama to Salamanca. The absence of high hills capped by the Panama conglomerate between Panama and Salamanca must therefore be taken as sufficient proof that the formation was not a pebble rock nor even a thick and massive sandstone. We have a right therefore to assert that the exhibition in the Panama district of pebbles and massiveness is a local feature of the formation. We have a right to suppose that originally, to the northward, over Lake Erie, in the air, the deposit varied in the same manner. Lastly we have a right to expect that if we follow the deposit from Panama southward into Pennsylvania similar variations will occur ; and that the field geologists will have no right to expect to see the typical Panama conglomerate, either in surface exposures or in bore holes, in Warren county. Mr. Carll proves that the facts correspond in this respect with the theory. Following the Panama southward, he finds it sinking at a slow angle to water level on the Broken Straw, and changing as it sinks from an immense massive pebbly formation to the ordinary sands and shales of the Chemung formation. If then it be in fact one of the Oil Sands of Venango county, the Third Oil Sand for instance, it must in passing through Warren county into Venango gradually or suddenly reassume its massive pebbly character. But these variations in the constitution of the deposit throw the geologist off the track and make the identification almost impossible.

Another obstacle rises to increase the difficulty of the situation. Variations in the Panama conglomerate such as have been described are merely such as all other beds and groups of beds in the series suffer to an equal degree; so that there is absolutely no such thing as mathematically definite and parallel stratification; every stratum thickening and thinning in every direction; growing harder and more massive in one direction, softer and thinner in another; wedging in between the stratum above and the stratum below it; changing its constitution and its color continually; and in this way concealing itself in neighboring exposures. It cannot be too earnestly insisted upon that there is no such thing as a valid generalized section; there are nothing true but local sections, single individual specimen sections. The field worker must reconcile himself to the necessity of restraining his imagination and working patiently from one exposure to another without the slightest hope of ever being able to put his local sections together in a perfectly systematic manner. Even where two neighboring local sections seem to resemble each other it would be found, if the whole outcrop between the two places could be laid perfectly bare, that hardly a single stratum in one section would be traceable in its integrity to the other. This statement however must be restricted to those piles of sand and clay deposits which make up the great Chemung formation, including the Venango Oil Sands and the rocks above them up to the great conglomerate. The moment we reach the Olean conglomerate we obtain a grand continous identifiable key formation from which one can measure downward; and it will be seen hereafter that we have many such fixed horizons in the coal beds and limestone strata of the coal measures.

Nonconformability of deposition, i. e. the irregular spreading out of one stratum upon another, or the wedging to nothing of one stratum between two others, letting them come together, is not confined as the geological text books would give the impression to a few occasional horizons in the palæozoic system, but is absolutely universal throughout it from top to bottom; and this must be remembered and taken into consideration in an especial manner when we study the great Chemung formation. It is, therefore, quite possible that the Leboeuf conglomerate should lie 750′ beneath the Olean conglomerate in one place and only 440′ beneath it at another.

On the other hand, while nonconformability pervades the entire Chemung formation the law of compensation works perpetually against it; i. e. while we must expect every stratum in a local section to thin away to nothing in all directions we may be perfectly sure that they will be replaced practically by an equal number of strata which come in to supply their place and keep the general section at other localities to about the same thickness. This law of compensation in the casting down of sand and mud upon the bottom of a water basin must be kept in mind and applied in explanation just as carefully as the other and opposing law of universal unconformability. And in the light of this law of compensation it becomes improbable that the Leboeuf conglomerate should be at one place 750′ and at another place only 440′ beneath the Olean conglomerate. In fact, the law of nonconformability presents such a fact only in a *possible* light whereas the law of compensation presents it under a *probable* light; in other words, it is possible, but not probable, that the Leboeuf conglomerate should underlie the Olean conglomerate by 750′ at one place and only 440′ at another.

Carll's discussion of the Panama conglomerate.

Before proceeding farther, the data for Mr. Carll's calculation will be given.—Within three miles of Panama, going south or southwest or west, we can inspect from 125′ to 225′ of overlying shales, bluish-green, olive, or brown, with occasional local sandy flags; no massive sandstones; nothing to remind one of the First and Second Venango Oil Sands; but numerous layers crowded with shells: Spirifera, Rhynchonella, etc. all Chemung types; the whole pile exactly resembling the pile of strata underneath the Panama conglomerate, which have always been called Chemung; so that the Panama conglomerate seems to be merely one stratum of the Chemung formation*.

* Mr. Carll's study of the quarries in Erie and Crawford led him to doubt any systematic connection between them; to regard them all as acci-

Following the *Panama conglomerate* southward, it is seen plainly marked in several places on the west side of the Little Broken Straw valley by steep bluffs, but so covered with drift as to show only its form and not its constitution. But a little more than three miles south of Panama the Eureka oil well started on its upper surface; passed through sandstone or sandy shales 60′ to 80′; then blue mud rock; then a quantity of very *red shale;* then soft shales with an occasional thin layer of fine sand; then a coarse, massive sand rock 18′ thick, with considerable oil; finally slate 15′ to bottom of drill hole, 456′ from surface. The well was remarkable for having no water. The Panama conglomerate at its mouth was unmistakable; with a top massive stratum of pebble sand; the rest 6″ to 15″ layers of fine grayish sandstone, with thin soft greenish shale partings. Top at Panama, 1671′; at well, 1569′; fall per mile (S.) about 32′. The remarkable fact is the red shale.

About a mile south of Eureka well, still in New York, is a small quarry of close, hard, bluish-gray sandstone in 4″ to 12″ layers; some pebbles in the top layers; many of the usual Panama fossils. Top, 1545′.

A mile and a quarter southeast (quarter mile south of state line) an exposure at W. H. Price's, Freehold township, shows the pebbly layers. Top, 1510′. Only the lower pebbly layers are left on the conspicuous dome-shaped hill, rising 250′ from the surrounding valley beds.

Passing the State line (five miles from Panama) to Bordwell's farm, one mile south of the State line, loose blocks of Panama conglomerate cover fifty acres, 30′ above the creek. Yet there is not the slightest trace of an outcrop along the hillsides; and these blocks must be brought down by the

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dental, local layers of sand in a general formation of shale; and thus to agree with Mr. James T. Hodge's conclusions in 1837, published by Prof. Rogers in the Geology of Pennsylvania, 1858, vol. II, page 583, where he says, "The thickest sand beds measure in some places 12″ or 15″; and where a number of them occur together with only thin partings of shale, the mass is quarried as a building material. It is seldom possible to trace a particular stratum of sandstone for any considerable distance, for the beds soon thin off or deteriorate for economical uses by becoming argillaceous, and thus they fade into the great body of the formation."

ice from the north.* No outcrop of Panama conglomerate is known on either side of the Little Broken Straw south of the State line. What is more surprising is that no trace of it even as a thin-bedded sandstone was found in the Lottsville oil well, three miles further down the stream. The 32′ dip, if continued to the Lottsville well, would bring the top of the conglomerate 41′ down from the mouth of the well ; but the well record asserts that the first 90′ showed sandy shales ; then 20′ of soft *red rock.* If these red strata are the red shales at Panama, the Panama conglomerate must have changed into sandy shale.

Below the Lottsville well 10′ (in the creek bed at 1440′) appears a thin but irregular greenish-yellow sandstone, coarse-grained in spots, 1′ thick ; with bluish-gray shales and flags full of *seaweed* markings, and smelling of oil ; also above the well mouth some very thin layers of conglomerate. This puts the top of the Panama conglomerate not 41′ down in the well, but above its mouth (say 1440′), and reduces the dip from the Eureka well to 28′ or 25′ per mile.—A dip of 27′ to the mile would carry (southward) the *Panama conglomerate* down to 1440′ under Miller's cliff (half way to Wrightsville), or 440′ underneath the *Miller's cliff conglomerate* (base 1840′ A. T.).—Wrightsville is two miles south of Lottsville ; and in its neighborhood are numerous exposures of a conglomerate sandstone, 15′ to 20′ thick, with flat pebbles, the *top* of which lies at 1600′; i. e. say 215′ above the *top* of the *Panama.*† This is Mr.

* Erratic boulders of Canadian gneiss are mixed with these conglomerate blocks ; and it is probable that a glacial-moraine was dropped like a great dam across the valley here, and afterwards cut away by the present stream, leaving a vertical wall of drift 20′ to 30′ high on its eastern bank, and these scattered blocks on its western bank. Should an outcrop be discovered here to explain the blocks differently it would add strength to the general proof of a dip 32′ per mile southward between Panama and the Eureka well.

† Its outcrop runs north along the bank of Miller's cliff hill, the interval between the base of the cliff above (1840′) and the top of the outcrop below (here 1620′) is therefore about 220′. The Wrightsville rock is in some of its exposures very similar in appearance to the Panama conglomerate ; yellowish, iron-seamed ; containing numerous fossils, among which are noticeable two or three species of Spirifer and a small Aviculopecten. It evidently turns into flaggy sandstone in various directions.

Carll's *Wrightsville conglomerate.*—Garland is eight miles south of Lottsville (six south of Wrightsville) on the Erie railroad and Big Brokenstraw creek (its *quarries* on the hilltop a mile north of it) *Olean conglomerate, base 1810′ A. T.*—A dip of about 26′ per mile for 7 miles ought to place the *Miller's cliff base* here at about 1620′; the *Wrightsville rock* (*top*) at about 1400′; the *Panama rock* (*top*) at about 1220′ A. T.

Cotter Farm (*Garland*) *section* (*I4, p. 258*).*

Olean conglomerate at quarries, ...		*base*	1810′ A. T.
Sandy shales (mostly) partly concealed, ...	200′		
Miller's cliff rock; thin bedded sandstones, . .	20′?	*top*	1610′
Sandy shales (apparently) partly concealed, . .	135′		
Wrightsville conglomerate, flat pebble, etc.,† . .	15′	*top*	1455′
Shales { bluish, with some thin sand plates, 65′; one layer of fine grained clay sand, . 1′; bluish and brown, a little sandy, . 41′ }	107′		
Sandstone, quite massy, greenish gray,‡ . . seen,	3′	top	1333′
Concealed, ...	18′		
Slate, blue, gritty, 6′; sandstone, gray, 2′; slate, 11′; sandstone, 2′; slate, 49′; shale 30′, ...	100′		
Panama; sandstone, white, flinty (oil show), .	40′	top	1217′
Soapstone, 54′; slate gritty, with quartz, 18′, . .	72′		
Red rock drillings,§	4′	top	1105′
Soapstone 5′; slate and white sand plies, 16′; soapstone, 43′, ...	64′		
Sandstone, quartz (thick oil and gas), ...	2′	top	1037′
Soapstone (oil show), ...	35′		
Sandstone (crevice), ...	2′	top	1000′
Soapstone (oil show and soot) 20′; slate, 10′; soapstone, 14′, ...	44′		

*Laid bare and beautifully exposed by a large land slip in 1882.

† Small flat pebbles; iron stained, current bedded, massive rock, weathering into small blocks.

‡ This sandstone may be 10′ thick, if it be the stratum at 1343′–1333′ in the section at point of bluff (on page 259). The concealed interval is occupied by the conductor hole of Well No. 1 (Report I2, p. 196) mouth at 1330′; creek level at 1315′.—It represents also the *Hosmer run conglomerate;* which is the *Venango First oil sand* (I2, p. 165). The *Garland section proper* (at the point of bluff, 80 rods west of the station) gives:—Sandy shale 15′; *Spirifer bed* (a sandstone, weathering brown, a mass of *shells*) 2′; brown shales 5′; *Cotter farm (?) sandstone* 10′; sandstone layer with *shells* ½′; fissile shale 18′; sandstone layer with *Spirifers,* ½′; shale 2′; to railroad level, 1311′ A. T.

§ Compare red rocks under conglomerate at Panama.

Sandstone,	4′	top	954′
Soft drilling not described,	240′		
Slate, hard,	5′		
Soapstone and slate,	97′		
Sandstone,*	7′	top	598′
Slate, soft and soapy 8′ to bottom of well (583′).			

The *Miller's cliff rock*† was at first identified with the *Olean conglomerate* (although too low A. T.) because of its aspect, and because it seemed to be the most northern outlier of that formation in Warren county; and so the *Panama* seemed to lie only 430′ beneath the *Olean*, which would have made it rather the First than the Third Venango oil sand; but by recognizing the Miller's cliff rock as *Sub-Olean*, all difficulties are removed (for its purely sandstone character at Garland merely tells the common story of all pebble deposits); and thus Mr. Carll's and Mr. White's measurements are brought into substantial agreement.

The Pope's Rock outcrop.

Having traced the *Panama conglomerate* southward along the Little Brokenstraw to Garland, we will go further east and do the same from Pope's Hollow in New York down the Conewango to Warren. But first some connection must be made from the west to east; and this can only be done by following the outcrop belt of the *Wrightsville conglomerate* through Sugar Grove and Farmington townships by means of a number of partial sandstone exposures to McCoy's farm in Pinegrove township (2½ miles N.

*Called "Third sand" in the record kept by the drillers; but having nothing at all to do with the Venango Third oil sand; being 1810′—598′=1212′ beneath the Olean conglomerate.

† *Miller's cliff* base is 1840′ A. T.—*Drake's rocks* (2½ miles S. S. W.) are *Olean*, 1890′.—*Pike's rocks* (3 miles E. S. E.) are *Olean*, 1980′.—*Nuttall's rocks* (1¾ miles S. of Pike's) are *Olean*, 1955′.—There is no sign of a reversed N. or N. W. dip; and these are only hill tops which have preserved the formation and furnish data. In I4, 229, it is suggested that perhaps the *Sub-Olean* deposits were removed and the *Olean* deposit made at a low level; but I see no call for such an hypothesis, either in this or in another instance to be mentioned hereafter. The Sub-Olean conglomerate was positively identified by Mr. Carll by its yellow iron-stained aspect only in Pike's hill, and not in the others. It is certainly not to be found in the Miller's cliff hill, unless it be the Miller's cliff itself.

E. of Russelburg on the Conewango) two miles south of the State line.

The *Pope's Hollow conglomerate* exposure in New York is 6 miles N. N. E. of McCoy's, on Case run, 5 miles east of Frewsburg. A massive flat pebble conglomerate, 20′ thick; pebbles growing more numerous until at the east end of the exposure the whole rock is a mass of flat pebbles; top, 1940′ A. T.*

As at Panama oil wells have gone down 1200′ without striking a massive sandstone of any kind whatever, so here 500′ of soft strata are visible beneath the Pope's Hollow conglomerate without a trace of any sandstone stratum that can be called hard or massive (Chance's report to Carll, I4, p. 181.)—McCoy's cliff juts from the hillside and throws great blocks into the valley below; massive sand rock strata, more or less pebbly all through, current bedded, seamed and discolored with iron; top, 1800′ A. T.—Brigg's oil well No. 2, near the south line of the township, show the rock plainly at 1705′.—From Pope's Hollow to McCoy's, average dip 23′ per mile; McCoy's to Briggs No. 2, average dip 27′ per mile; Briggs No. 2, to Asylum quarry on Follet's run Conewango township (2 miles N. W. of Warren) distance 4½ miles S. S. W. (top 1585′ A. T.) average dip 27′ per mile:

Pope's Hollow conglomerate below *Sub-Olean*,† . . .	230′
Asylum quarry rock below *Sub-Olean*, ...	270′
Wrightsville conglomerate below Miller's cliff, . . .	220′

From McCoy's eastward the *Pope's hollow conglomerate* cannot be traced continuously to the Olean district. Exposures of it indeed occur for a few miles east of McCoy's

*Spirit leveled by Chance and Hale from rail at Frewsburg. Panama rock spirit leveled from rail at Grant, 1691′. Ellicottville rock city spirit leveled from rail at Salamanca, 2190′. Panama east to Pope's Hollow 20 miles. Pope's Hollow N. E. to Ellicottsville rock city (Salamanca cong.) 22 miles.

†The calculation is made thus: One mile east of a line joining Pope's Hollow and McCoy's a little north of the state line, a fine cliff of *Sub-Olean* has its base at 2100′, and about half way between Pope's Hollow and McCoy's. Calling the rise regular at 27′ per mile, the Pope's Hollow rock would lie at 1870′ under the cliff.

in Pinegrove; but none were seen in Elk; nor across the Allegheny river in the hills back of Corydon in McKean Co. although such may exist, as they would be easily missed by a field geologist passing close by them in the thick underwood of the forest.*

The Ellicottsville Conglomerate.

The Salamanca conglomerate of Ellicottsville rock city crowns a ridge running north and south between the Little valley and the Great valley in Cattaraugus county, N. Y. 3½ miles north of Salamanca. The rock cities here and at Panama suggest a similar origin and like conditions of deposition, whether they are on the same geological plane in the series of strata or not. The top of the rock is at 2190′ A. T., and its outcrop can be traced without any uncertainty from the rock city to the south end of the ridge just north of Salamanca. It is seen again in the hill south of Salamanca, and again on the point of high land just north of Carrollton at 1975′ A. T. The fall (S. S. E.) of 215′ in about seven miles gives an *average dip of 30′ to the mile;* all the intermediate exposures agreeing well with this rate.—Three miles further (S. S. E.), where Tuna (Tunangwant) creek enters the Allegheny, this dip should bring down the rock to 1885′ A. T. but no exposure appears. But a rock city, of similar flat pebble sandstone 25′ thick caps the point of the hill 285′ higher, its top being 2120′ A. T. †

This *Tuna conglomerate* dips southward up Tuna creek valley. Along the eastern slope of the valley are exposed above it 250′ of gray and red shales and shaly sandstones, without any higher conglomerate. But on the west slope of the valley at Ireland (three miles southwest from the

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*On the Tuna (Tunianguant) creek in McKean Co. however flowing north past Bradford to join the Allegheny river near Carrollton, Cattaraugus county, New York, appears a conglomerate which probably occupies the Pope's Hollow-Wrightsville Conglomerate horizon; with the Salamanca (Panama?) conglomerate beneath it; and two others above it, as on the Brokenstraw. A north and south section from Salamanca to Bradford was here made by Mr. Carll, and described in his Report I4, 203.

† This *Tuna conglomerate* then holds to the Salamanca rock the same relation that the *Wrightsville conglomerate* holds to the Panama further west.

last exposure, 3 m. n. of the line) Irish run cuts through a similar conglomerate (top 2000′), its blocks strewing the valley below. Soft rocks overlie it for 250′; but where a notch has been cut in the extreme top of the ridge lie a few very large block-masses of a pebble rock (base 2270′) where the *Sub-Olean Conglomerate* ought to be.

Thus, in New York, we have a series of three conglomerates: first and lowest, the Salamanca; then 235′ above it, the Tuna; then 275′ above that, the Ireland Sub-Olean?

In Pennsylvania, just south of the State line (3 or 4 miles south of the Irish run rock) Buchanan hill is capped with a flat pebble sandstone weathering in thin plates (top, 2200′) which ought to be the Ireland or uppermost of the series in New York. Beneath it, 300′, runs a well marked terrace where the *Tuna conglomerate* would come if the south dip was continued unchanged.

Passing on still southward four miles further up the Tuna valley to Tarport, Mount Raub (south of Tarport) shows a conglomerate at (top) 2170′; 258′ beneath which lies (according to a well record) a 20′ sand, between upper and lower red shales, at 1912′. (I4, 205.) The average dip obtained between Salamanca and Tuna in New York, holds good past Ireland to Buchanan hill just inside the Pennsylvania State line; the Buchanan hill rock and the rocks at the notch in the hill top west of Ireland are undoubetedly the same; but now if the Mt. Raub rock be the same, the average dip southwardly must flatten from 30′ to only 8′ per mile.*

*A much more curious and startling fact is reported by Mr. Carll, viz: That the eastern brow of Mt. Raub shows the *flat pebble Buchanan hill conglomerate*, while the western brow, at exactly the same level (2170′) shows the regular *round pebble Olean conglomerate.* This case is as embarrassing as that of Miller's cliff on the Little Brokenstraw, Warren county, already described. Mr. Carll here again suggests as a possible explanation that the *Sub-Olean* in one part of the hill has been eroded before the deposit of the *Olean unconformably* on lower measures, in the hollow thus left. But before accepting such a theory we must become more certain than we are that the Olean is absolutely everywhere a round pebble gravel and the Sub-Olean absolutely everywhere a round flat pebble gravel (see foot note to I4, p. 205).—But instead of that it is demonstrated that the southward dip for at least a dozen miles south of the State line in northern McKean county exceeds 20′ to the mile, thus: from Coryden hill (2175′+)

The Dennis well section.

The famous *Dennis Well No. 1*,* with an exceptionally trustworthy record, 2 miles west of Mount Raub and 3+ miles south of Buchanan hill, was started on the high ridge west of the Tuna creek less than a mile S. S. W. from Bradford. *Olean conglomerate* caps the ridge near the well, its base being 2170′ A. T. The well mouth is 2055′ A. T. Sandstone strata were struck in the well at 2040′, 1988′, 1939′, 1917′, 1840′, 1740′, 1727′, 1665′, 1582′, 1475,′ 1369′ 1313′, 1112′, 999′ (Bradford First), 978′ 967′, 944′, 755′, 710′ (Bradford second), and 391 A.T.(Bradford Third, or main oil sand). Their respective thicknesses were reported as—33′, 31′, 16′ (*underlaid by 6′ of red shale*), 59′ (*underlaid by 18′ of red shale*), 23′ (*with a few pebbles, the only one of the whole record so distinguished*), 5′ (*8′ of red shale*), 39′ (*15′ of red shale*), 45′, 12′ (*fossils first got*), 94′ (*fossils*), 36′ (*fossils; lower 10′ red sand*), 76′ (*fossils, and very red shales*), 8′ (*red, and fossils*), 16′ (*1st Sand*), *10′* (*fossils*), 14′ (*oil show*,) 17′ (*fossils*, 36′ (*2d Sand*), 54′ (*3d Sand*)= 624′ of sandstone strata in a total depth of 1834′, or one-third of the whole, the rest being soft drilling or shale, mostly *Chemung*.

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to Kinzua hills (1975′) along the Warren county line, eleven miles, *18′ per mile due south.*—From Marillo summit in western Bradford township (2150′) to Marsburg in Lafayette township (1975′) eight miles, *22′ per mile due south.*—From Bradford to DeGolian, three miles, 12½′; and from DeGolian to Lewis run, two and a quarter miles, 37′; average of five and a qearter miles, *21′ due south.* From Bradford (*S. 40° W.*) to Marshburg, nine miles, 21½′; and from Bradford (*S. 40° E.*) to the southeast corner of the township, seven and a half miles, 14′ per mile.—From Olean Rock city (2340′) to Smethport (2025′) fourteen miles, *22½′ per mile due south.*

* Dennis well No. 1 is distinguished among the hundreds of Bradford oil wells for the accuracy of its record. Messrs. C. W. Dennis & Co., and their drillers consented to subject themselves to the annoyances attending frequent measurements and the preservation of sand pumpings under the direction of Mr. Arthur Hale, one of Mr. Carll's aids in the survey of the oil region, in February, 1878, who from the time the tools were swung in the derrick until the last sand pumping came up, devoted his whole attention to it, and probably no well record was ever kept with greater care or more in detail than this one. A portion of nearly every sand pumping was preserved, and the suite of specimens, bottled and arranged to a scale of one-fiftieth, as described by Mr. Carll in Report I3, page 20, gives a good exhibition of the character of the measures drillad through. The record and catalogue of drillings may be found in I3, pages 226 to 229; and in R, p. 287.

Dennis Well No. 1, at Bradford.

	A. T.
Olean conglomerate at the top of the hill a short distance south of the well,	base 2170′
Well mouth,	2055′
Surface clays,	4′ to 2051′
Sandy shale, olive-gray, micaceous,	11′ to 2040′
Sandstone, gray, fine, micaceous,	33′ to 2007′
Shale, dark gray (thin micaceous sand plies),	19′ to 1988′
Sandstone, gray, fine, soft,	8′ to 1980′
Sandstone, slaty, bluish, fine-grained,	23′ to 1957′
Slate, dark, alternations with fine gray sand plies,	18′ to 1939′
Sandstone, ash-gray, very fine, micaceous,	16′ to 1923′
Red shale, soft,	6′ to 1917′
Sandstone, olive-gray, fine, micaceous,	12′ to 1905′
Sandstone, dark olive, gray, fine micaceous,	30′ to 1875
Sandstone, white, green, and brown, fine,	8′ to 1867′
Sandstone, bluish-gray, fine, micaceous,	9′ to 1858′
Paint rock, red shale, top soft, bottom sandy, mica.,	18 to 1840′
Sandstone, gray, fine with slate (a few pebbles),	23′ to 1817′
Slate, bluish,	22′ to 1795′
Slate, bluish, with thin plies of fine sandstone,	15′ to 1780′
Slate, sandy, dark gray, fine, micaceous,	16′ to 1764′
Slate, bluish,	24′ to 1740′
Sandstone, gray, fine, micaceous,	5′ to 1735′
Red Slate, micaceous,	8′ to 1727′
Sandstone, olive-gray, soft, micaceous, slate partings,	39′ to 1688′
Red shale, sandy, mottled, brown, green, gray,	15 to 1673′
Slate, sandy, gray,	8′ to 1665′
Sandstone, dark, very fine,	10′ to 1655′
Sandstone, gray, very fine, hard (drillings like flour)	35′ to 1620′
Slate, sandy, micaceous,	38′ to 1582′
Sandstone, dark gray, very fine, micaceous, flaky,	6′ to 1576′
Sandstone, blue-gray, fine, hard (*fossil shells*),	6′ to 1570′
Slate (sandy plies) micaceous (*fossil shell beds*),	95′ to 1475
Sandstone, dark gray, thin bedded, fine, micaceous, slate partings (*fossil shells*),	71 to 1404′
Sandstone, gray, fine, flaky, micaceous (*fossil shells*),	23′ to 1381′
Slate,	12′ to 1369′
Sandstone, dark gray, slate partings (*fossil shells*),	26′ to 1343′
Red sandstone, very fine, micaceous (*fossil shells*),	10 to 1333
Slate, sandy, dark, micaceous,	20′ to 1313′
Sandstone, fine, micaceous, alternations of slate and *chocolate colored* shales (*fossil shells*),	63 to 1250
Sandsone, thin bedded, micaceous, slate partings (*fossil shells*),	13 to 1237′
Slate with an occasional sand ply (*fossil shells*,	125′ to 1112
Sandstone, *purplish*, fine, hard (*fossil shells*),	8′ to 1104
Slate, dark lead-color,	55′ to 1049
Red rock, *purple* and gray, sandy slate, fine,	14′ to 1035′
Slate and sand plies, gray (*fossil shells*,)	24′ to 1011′
Slate,	12′ to 999

Bradford first sand, dark, hard, fine,	3	
" " " yellow-gray, fine as flour,	13′	to 983′
Slate,	5′	to 978′
Sandstone, yellow-gray, fine,	4′	to 974′
Slate, sandy,	7′	to 967′
Sandstone, dark gray, fine (*fossil shells*),	6′	to 961′
Slate,	17	to 944′
Sandstone, fine, soft, some slate (*oil show*),	14′	to 930′
Slate,	23′	to 907′
Slate with dark sand plies,	15′	to 892′
Slate,	13′	to 879′
Slate with gray sand plies,	5′	to 874′
Slate,	12′	to 862′
Slate with occasional sand ply,	44′	to 818′
Slate ("blue slate"),	63′	to 755
Sandstone, brown, fine, flaky, slate partings (*fossil shells*),	17′	to 738′
Slate,	28′	to 710′
Bradford second sand, dark, fine, close, hard,	6′	
" " " brown-gray, fine, slate partings,	30′	to 674′
Slate with sand plies,	22′	to 652′
Slate with one sand ply at 1428′,	59′	to 593′
Slate and fine sand ply alternations,	25	to 568′
Slate with three sand plies at 1510′, 1531′, and 1573′,	118′	to 450′
Slate with sand plies,	27′	to 423′
Slate,	32′	to 391′
Bradford Third sand, brown, fine, flaky, sandstone,	54′	to 337′
Slate and sandstone,	1′	to 336′

In this Dennis well the Salamanca conglomerate is not represented as a pebble rock; but fossil shells appear first in the well at 1570′, i. e. 600′ beneath the Olean, and are abundant down to 1011′. At 1475′, i. e. 700′ beneath the Olean, we have the top of 94′ of sandstone with fossil shells. Thus from Carrollton in New York, where the Salamanca conglomerate is well exposed, to the Dennis well twelve miles south of it, the conglomerate has completely changed its character by losing its pebbles and becoming a fine-grained micaceous sandstone with slate partings. This is precisely what happens to the Panama conglomerate when traced ten miles southward to the Lottsville well, except that a thin layer of pebbles is seen there 10′ above the mouth of the well.

If the Buchanan rock (top, 2200′) falls southward for three miles at the New York rate (30′ per mile) its top should be at 2110′ (55′ above the Dennis well mouth) i. e. 50′ beneath the *base* of the *Olean*, which is exactly the place of the

Sub-Olean. The *Tuna* rock would then be 250′ or 300′ down in the well (1800′ or 1750′) near its Fifth sandstone. The Salamanca rock would come in the well at 1500′, or perhaps at 1475′, where the drill struck the top of a continuous series of thin bedded sandstones, dark grey, fine grained, micaceous, with shale partings, holding fossil shells, 71′ thick. Utterly different in constitution as these strata are from either the Salamanca, the Tuna, or the Buchanan hill conglomerates, they are no more so than are all the other sandstone strata pierced by the Dennis well. For the fifth sandstone although holding a few pebbles, does not break the general rule, being fine grained with slate partings. They are all fine grained; and show plainly enough how impossible it is to trace any one of these conglomerates as soon as it begins to change into ordinary fine sands and shales at the distance of only a few miles from its rock city exposure.

Chapter CIV.

The Venango Group in Venango county; and in Western Pennsylvania.

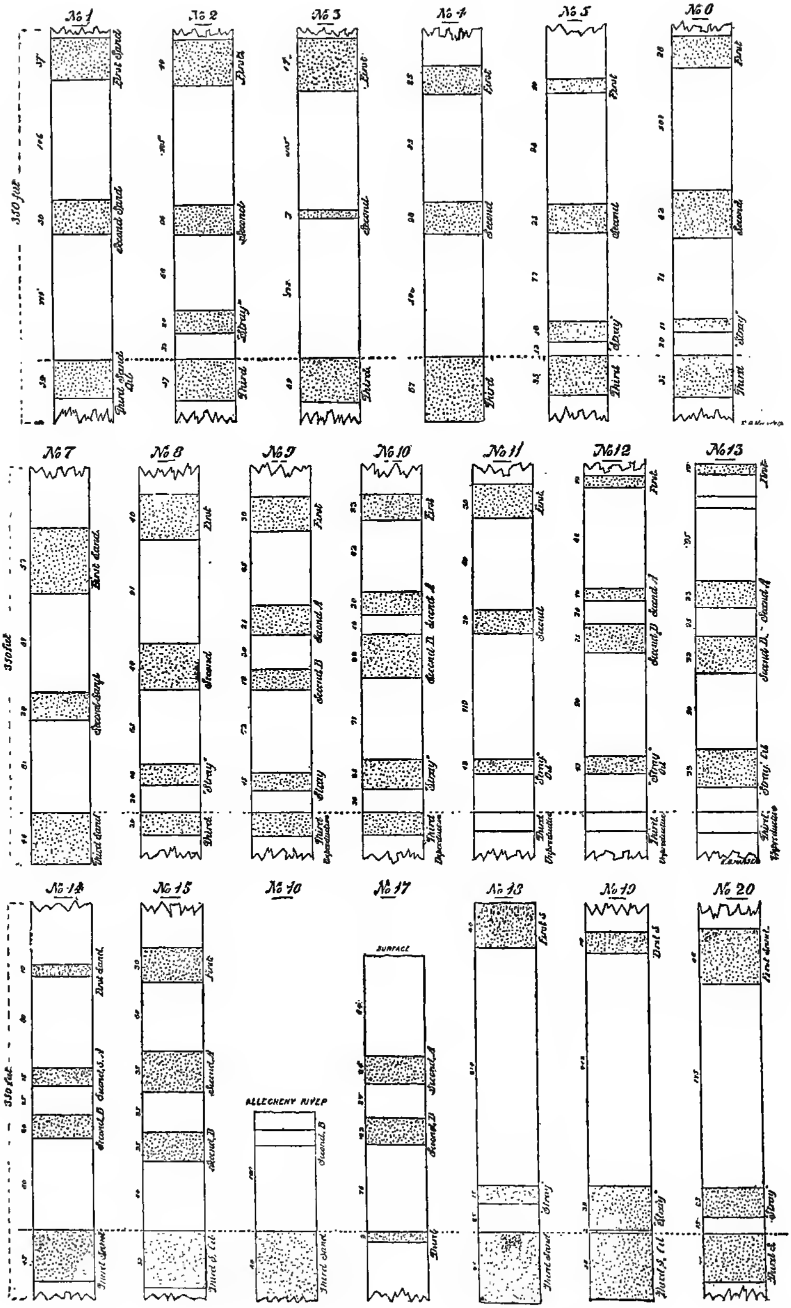
The three oil sands were first studied, and their continuity first proved by the early wells in Venango county. It was seen that the sands were in places sub-divided or parted into two, one of which was always called a "split." The second and third sands were frequently split; the first remained almost everywhere single and solid. To illustrate this feature of the group Mr. Carll in his First Report, 1874, selected twenty well-records which he could rely upon and arranged them as columnar sections on three page plates (pp. 25, 27, 29), the top of the third sand being used by him as a horizontal base-plane to which the sections were adjusted for comparison. See Plates 203, 204, next page.

On Oil creek where the group is very regular Mr. Carll found the following a fairly correct *average record:*—First Sand, 40′; interval shales, 105′; Second Sand, 25′; interval shales, 110′; Third Sand, 35′; total 315′ (I, p. 14).

The "Stray Third," produces a much darker and often a nearly black petroleum when found in some parts of the belt, as at Pleasantville, where it lies 15′ to 20′ above the Third Sand, and varies from 12′ to 25′.*

* Here it was called the Black Oil Sand. At East Shamberg and other places wells in close proximity to each other produced, some of them black oil, some green oil, and some a mixture of the two kinds. The Stray Third is here a typical gray fine mud-sand and produces no oil; but in the other places it becomes a productive gravel bed. At Pleasantville for instance it is a coarse pebble or conglomerate, whereas the Third Sand under it is there a fine micaceous mud-sand, only 15′ to 20′ thick, showing traces of green oil and sometimes charged with gas. But even in the color of the oil there are no fixed relationships for the Pithole, Cashup and Facundus wells drew a lighter oil from the Stray Third. On the N. W. side of the belt the Stray is poor and the Third rich; on the S. E. side the Stray gets pebbly and produces oil over larger areas than the Third, which grows fine and compact and gradually thins away in that direction.

Chap. CIV. Pl. 103.



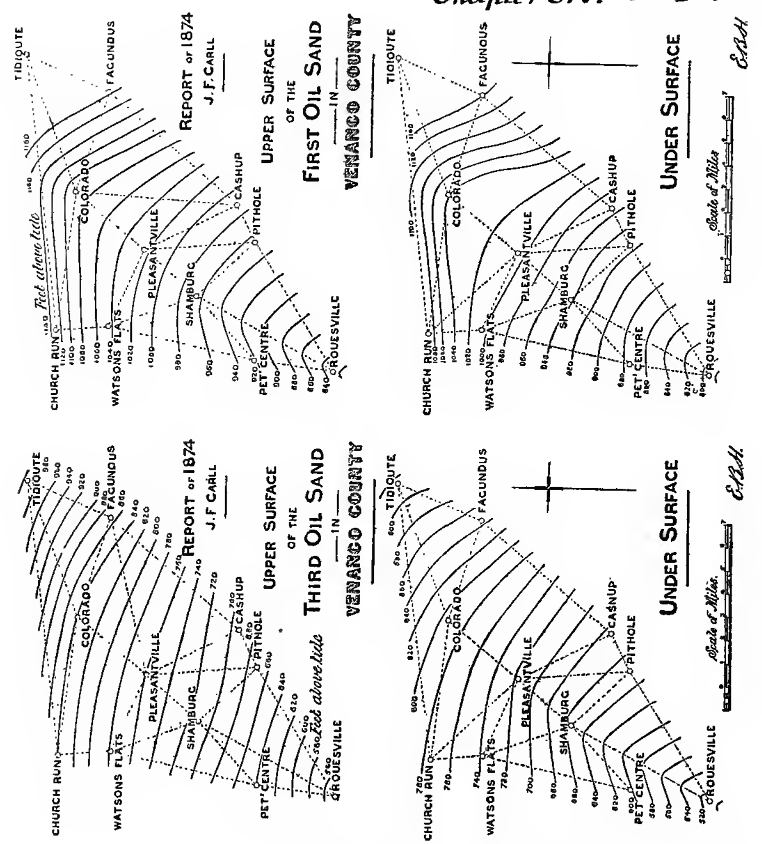
The twenty selected records were from those of 1, the Buchanan farm; 2, Tarr farm; 3, Petroleum Center; 4, 5, Shamburg; 6, Pleasantville; 7, Colorado; 8, Pleasantville; 9, Sears farm; 10, Cashup; 11, Pithole; 12, Rooker farm; 13, Fagundus; 14, Irvin farm; 15, Dennis run; 16, Tidioute; 17, Richardson farm; 18, 19, Church run; 20, Original Petr. Co. below Watson's Falls.

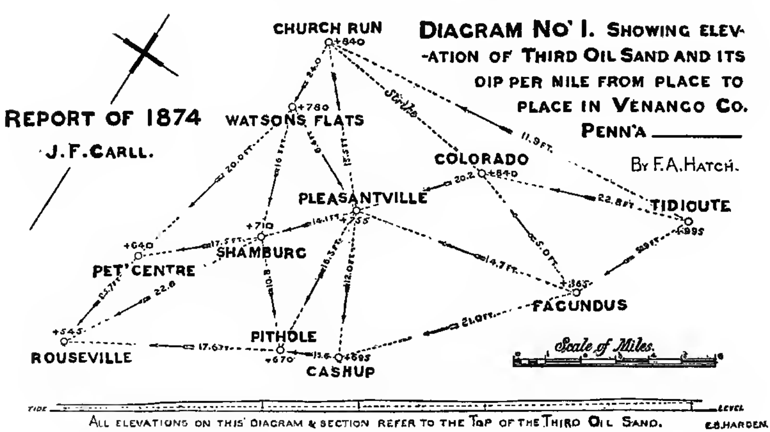
	First Sand.	*Interval.*	*Stray Second.*	*Interval.*	*Second Sand.*	*Interval.*	*Stray Third.*	*Interval.*	*Third Sand.*
1, ...	37	106	. .	. .	30	111	. .		35=319
2, ...	40	105	. .	. .	26	66	20	23	37=317
3, ...	47	105	. .	. .	7	123	. .	.	39=321
4, ...	25	95	. .	. .	28	108	. .	. .	67=323
5, . .	12	98	. .	. .	25	77	18	13	35=268
6, ...	28	107	. .	. .	42	71	11	20	37=316
7, ...	57	87	. .	. .	24	81	. .	.	46=295
8, . .	40	91	.	. .	40	65	18	24	20=299
9, ...	30	65	25	30	18	72	15	?	?
10, ...	23	82	20	16	38	71	25	20	?
11, ...	30	80	. .	.	20	110	12	?	?
12, ...	10	88	10	10	25	90	15	?	?
13, ...	10	95	23	25	32	100	33	?	?
14, ...	10	80	15	25	20	80	. .	. .	45=275
15, ...	36	60	35	35	25	60	. .	. .	50=301
16, ...	.	. .	. .	. .	. .	100	. .	. .	80
17, ...	.	84+	24	29	23	76	. .	. .	9
18, ...	40	210	. .	. .	. .	. .	15	25	64=354
19, ...	18	202	. .	. .	. .	. .	38	2	58=318
20.	48	175	. .	. .	. .	. .	25	15	41=314

Seven of the twenty do not give the total thickness of the group; but the thirteen that do suffice to illustrate the unusual parallelism of its top and bottom planes. Seven of them make the group 314, 316, 317, 318, 319, 321, 323 feet thick. This is a wonderful result, considering that the wells were bored independantly, by different drillers, and at distances of miles apart.

The measures lie almost horizontal, but with a normal slope or dip of about 20 feet per mile (from Tidioute to Rouseville) along the belt southwestward (see Carll's three plates I, pp. 15, 17, 19). There is a slight indication of a basin structure on the upper and under surfaces of the First sand, and on the under surface of the Third sand, but none at all on its upper surface. The belt is not in any sense a

Chapter CIV. PL. 204.





synclinal trough holding oil ; much less is an *anticlinal* on the summit of which the oil has accumulated ; and the oil was as abundant at the lower Rouseville end of the slope, as at the upper Tidioute end, a distance of 20 miles, and a difference of elevation of the upper surface of the Third sand of (1000 A. T.—540=) 460 feet, and of the under surface (920 A. T.—510=) 410 feet. It is evident that if the so-called "anticlinal theory" were a correct one it ought to apply here ; for this Venango belt held water, oil and gas together ; and yet the production of the wells showed plainly enough that the gas was not collected at the upper N. E. end, the oil in the middle, and the water at the lower S. W. end. The specific gravity of the three substances had no effect upon their distribution ; but they were everywhere mixed together ; and the gas being under great pressure not only kept the oil and water distributed throughout the belt, but blew them up together into the air from the well mouths ; and that with a far greater force than any hydrostatic fresh water pressure assignable to wells of such very moderate depth.*

In other counties of W. Pennsylvania.

The foregoing description will serve for the character of this remarkable group of sands in its wide extent beneath all the western counties where it has been reached and

*The anticlinal theory has been ascribed to Prof. I. C. White, but it was advanced many years before he began to work in Oil Geology. It was first adduced to explain the oil field of the "Great Break" in W. Virginia. I opposed to it then the simple explanation that the oil rocks were merely brought near enough to surface by the steep dips of that sharp broken anticlinal to be reached by the drillers who kept close to it. The older northern oil fields disproved it by a set of facts worked out carefully in northwest Pennsylvania by Carll and Ashburner ; and in more recent years by the fact of many productive wells in the synclinals and dry holes on the anticlinals. It has become evident that the location of productive wells has nothing to do with the anticlinal lines which sweep in broad curves from New York to W. Virginia through our western counties, but solely with the underground trend, local extent and local constitution of each oil bearing sand. The general direction of all these oil sand deposits was determined ages before the country was folded into anticlinal and synclinal waves ; and the two sets of phenomena—deposit and folding—happen to have a similar general direction (S. W.) but not exactly the same, often not at all the same (as in the Butler Co. Cross Belt); so that the deposits cross obliquely the anticlinals and synclinals.

passed through by the drill—in Clarion, Armstrong, Butler, Allegheny, Westmoreland, Fayette, Greene, Washington and Beaver, Lawrence and Mercer. To Mr. Carll is due the honor of proving by many years of patient research the fact of its universal outspread, its general uniformity of thickness along the wide belt from Warren to Greene, its extraordinary increase in thickness and change of character from this belt eastward towards the Allegheny mountain, the variability of its subdivisions locally, and the confinement of its oil and gas productiveness to streaks (belts) and spots (pools) of gravel and coarse sand which are the local reservoirs of oil and gas, while the finer sands and shales which constitute the great proportion of its outspread deposits are dry or barren ground.*

The slow and regular descent of the Venango group (in common with the formations above it) southward from Mercer to Greene county is given in Mr. Carll's table (Ann. Rt. 1866, part 2, p. 661) thus:—

Top of 1st Sand.†	*Above tide.*	*Distance. in Miles.*	*Fall in feet.*	*Rate of fall per mile.*
Hosmer run,	+ 1430′			
Church run,	+ 1100	13	330′	25
Franklin,	+ 723	18	377	21
Bullion,	+ 640	10	83	8.5
Petrolia,	+ 119	18	521	29
Great Belt,	— 166	14	285	20
Pittsburg,	— 790	28	624	22
Washington,	— 1150	23	360	16
Waynesburg,	— 1385	20	235	11.5
Total,		137	2815	20.5

* All this is clearly set forth in Mr. Carll's seventh report I5, 1890, pp. 80 to 92, with three page plates of columnar sections made from records of seven selected wells on the north and south line, and three on an east and west line.

† In this long distance of 130 miles in an air line the First Venango Sand is persistent and easily recognized by the geologist, although the drillers have given it various names in various localities. Its last outcrop northward is on Hosmer run in Warren co. (I4, p. 250); and from this southward "it may be followed in drill holes step by step to Waynesburg in Greene co. where it lies 2305′ beneath the surface, 1385′ below ocean level, and 2815′ lower than at our starting point Hosmer run" (Carll, 1866, p. 661).

Thickness of the group.

The thickness of the Venango Group is scarcely variable enough to attract notice along the straight line from Oil creek in Venango to the Ohio river below Pittsburg; being 305′ in the Lady Suffolk well on Oil creek; 300′ in the Haskell well at Pithole, 330′ in the Columbia No. 4 at Parker; 370′ in the Evans No. 21 at Petrolia; 357′ in the Marshall No. 21 at Thorn creek; and 392′ in the Hohmann, Allegheny county. The increase further on is more evident, as it is 436′ in the Cook in Washington county. If the line of observation were swung round more southwest no such increase of thickness would be perceived. But on cross lines a very different phenomenon presents itself; the formation, as such, grows thinner westward, and thicker eastward. Thus, it is 412′ at Hayes Crossing in Allegheny county; 509′ in the Jones and Laughlin at Pittsburg; and 664′ in the Daum well at Murraysville in Westmoreland county; where (and to the eastward) its sands turn into red or reddish shales, and its oil into gas. It is this geological fact that precludes hope of opening oil belts or finding oil pools in eastern Westmoreland, Fayette, Somerset and Cambria counties. It is doubtful whether we can recognize it under its changed aspect east of the Allegheny mountain, as will appear in the next chapter.*

* Mr. Carll says in his report of 1890, p. 86, of the group in Venango Co. that its Second sand thins out and disappears, and so do the enclosed red rocks. Towards the southeast and east the Second sand splits into two or more; the Third thins and becomes unproductive; red rocks interstratify with the sands; the group barely holds its thickness; and still further east loses all its sands and changes into Catskill red shales, 300′ at Wilcox, 460′ at Johnsonburg, and 520′ at Clearfield.—Of the Clarion-Butler belt he says that on the west no Second sand and no red rocks appear; but on the east the sands split up into many beds, red rocks increase in number, and the group thickens and becomes the red Catskill.—From Thorn creek to Waynesburg the sands are very irregularly deposited, and red shales flank its eastern edge and destroy its productiveness; they are found also in the wells at Mount Morris, Morgantown and Farmington along the State line country. Where the group is thickest, as at Murrayville in Westmoreland Co. (700′) its lowest sands always rest on the mass of Chemung shale. Deep wells in the Dunkard creek region of Greene Co. at Layton Station, Fayette Co. and at Waltz mill, Latrobe, Blairsville and Saltzburg in Westmoreland Co., the group is 700′ thick, with a large increase of reds. At Black Lick

The student of the Venango Group, and its relationship to the overlying formations, will find his best materials in the Fifth chapter of Mr. Carll's Report published in the Annual Report of the Survey for 1886, Part 2, pp. 636 to to 663 ; illustrated by a page plate map of Western Pennsylvania showing the geographical positions of 23 selected wells, scattered over the whole region from Allegheny Co. N. Y. to Greene Co. Pa. (on p. 638) ; and by page plates 1 to 5, exhibiting these 23 well records in the shape of minutely drawn columnar sections placed side by side for comparison. The text of the chapter is an admirable memoir on the geology of the oil region which well deserves republication as a reference tract for the use of oil and gas prospectors.

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and Canoe Lick in Indiana Co., the group is not so thick (but nearly all of it red. At Johnstown, Cambria Co., if the well record be reliable, the red (Catskill) has materially thickened.—Curiously enough in connection with the above statement, if a line be drawn from Bradys Bend on the Alleghany river through Pittsburg to Waynesburg in Greene Co. it passes to the east of all the *oil pools* yet discovered in the Butler sands in this district of the State. East of the line so indicated is a wide sweep of country in which very many test wells have been sunk, but only two or three have produced oil and very little of it; but it is a region of copious and strong gas.—As to the quantity of deposited sand in the group it may be said that in the Venango-Clarion oil fields the aggregate thickness of "the sands" seldom exceeds 120′ (one third of the whole thickness of the group), the average being considerably less; whereas in the Butler-Allegheny-Washington region the first sand alone sometimes measures 120′; and in many places the aggregate thickness of all the sands is 50′ greater than the entire thickness of the whole group in Venango Co. Therefore Mr. Carll argues that the source of supply of sand should be sought for in a southern direction.—I give in this note Mr. Carll's chief motive for assigning the Venango group to Catskill rather than Chemung age.

Chapter CV.

VIIIg, Chemung in Middle Pennsylvania.

We have seen that on Lake Erie the Chemung as understood by Prof. White is only 325′ thick, the underlying Girard shale only 225′, and the still lower Portage rocks 475′. If these be combined, we have 1025′. If the overlying Venango Group, varying between 250′ and 350′ (White) be added we have 1325′ more or less of formations which have all of them been called, whether justly or not, Chemung; all of them containing more or less Chemung fossils.

Against this moderate pile of deposits, sinking slowly underground southward and southeastward, to depths only passed through by the Conway well near Franklin, we have now to contrast their rising outcrops in the foothills of the Allegheny mountain, along a curved line 150 miles long, passing through Bedford, Blair, Center, Clinton and Lycoming counties, with a total thickness of 5000′ or 6000′ and more.*

It is needless to recount the outcrops of the Chemung as they zigzag across the Juniata and Susquehanna rivers. The reader has only to regard the zigzags of the Hamilton on page-plate CC (page 1338 above) as a specimen, remembering that the Chemung and Portage together make but one ridge, parallel to and separated from the Hamilton ridge by a continuous Genesee valley. This holds good throughout the region. The triangular cove between Peters mountain and Buffalo mountain north of it, east of the Susquehanna river (on plate CC), filled in with hills of Chemung, will serve as a specimen of the broad outspreads

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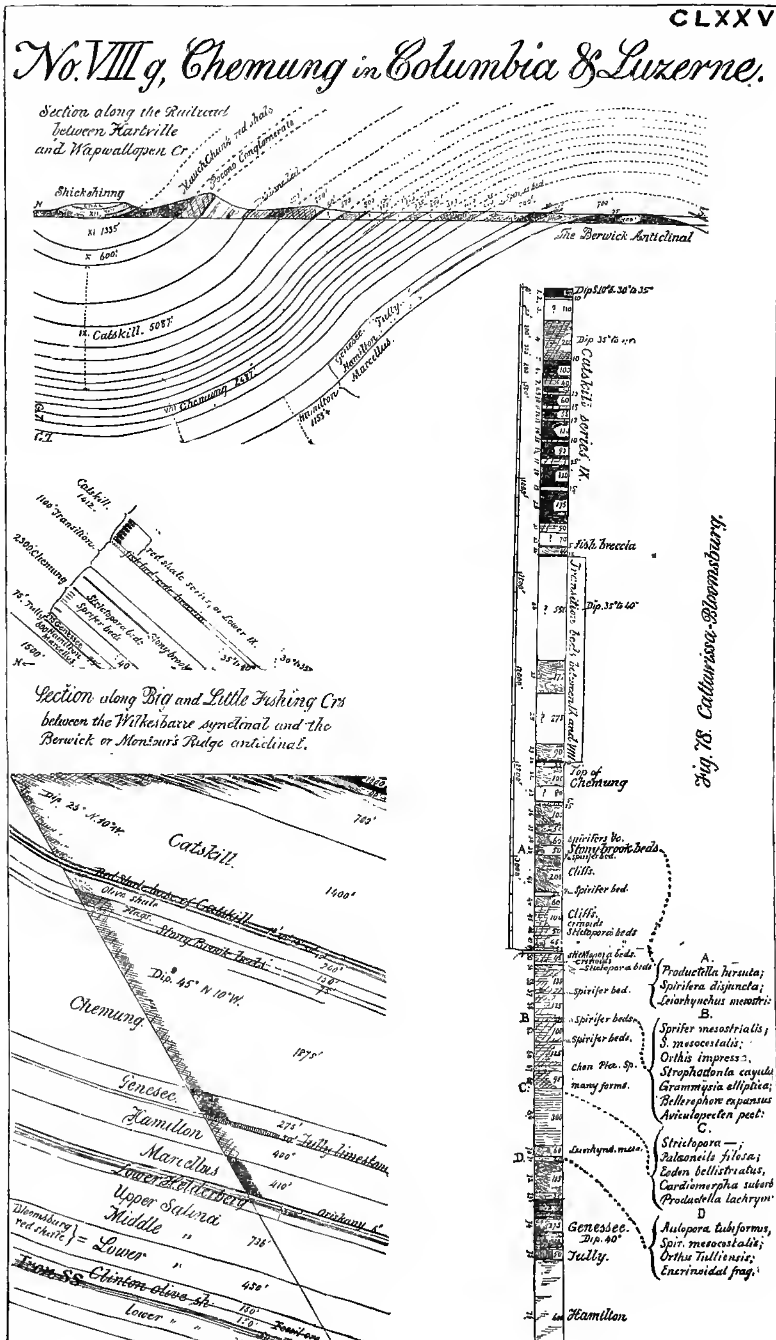
*The reader will refer back to 95 above for Prof. Stevenson's discussion of the subject which is beset with difficulties for those who endeavor the impossible feat of drawing lines across the column of sections for distinguishing its sub-divisions, as Catskill, Chemung, Portage, etc. which in fact run into each other.


CLXXV
No. VIII g, Chemung in Columbia & Luzerne.
Section along the Railroad between Hartville and Wapwallopen Cr.
Shickshinny
Mauch Chunk red shale
Pocono Conglomerate
XI 1335'
X 600'
IX. Catskill. 5087'
VIII Chemung
Genesee. Tully.
Hamilton.
Marcellus.
Hamilton 1155'
The Berwick Anticlinal
Catskill 1412.
1100' Transition.
2300' Chemung
75' Tully
Genesee
Hamilton
Marcellus
red shale series, or Lower IX.
Stictopora beds
Spirifer beds
Stony brook
Section along Big and Little Fishing Crs between the Wilkesbarre synclinal and the Berwick or Montour's Ridge anticlinal.
Dip 25° N.10°W.
Catskill.
700'
1400'
Red Shale beds of Catskill
Olive shale
Flags.
Stony Brook beds
Dip. 45° N 10° W.
Chemung.
1875'
Genesee.
Hamilton
Marcellus
Lower Helderberg
Upper Salina
Middle
Bloomsburg red shale } = Lower
Iron SS.
Clinton olive sh.
Lower
275'
Tully limestone
400'
410'
Oriskany
736'
450'
Dip S10°E. 30° to 35°
Dip 35° to 40°
Catskill series, IX.
fish breccia
Transition beds between IX and VIII
Dip. 35° to 40°
Top of Chemung
Spirifers &c.
Stony brook beds.
Cliffs.
Spirifer bed.
Cliffs,
crinoids
Stictopora beds
Spirifer bed.
Spirifer beds.
Spirifer beds.
Chon. Ptera. Sp.
many forms.
Genesee.
Dip. 40°
Tully.
Hamilton
Fig. 78. Cattawissa-Bloomsburg.
A.
Productella hirsuta;
Spirifera disjuncta;
Leiorhynchus mesostri:
B.
Spirifer mesostrialis;
S. mesocostalis;
Orthis impressa,
Strophodonta cayuta
Grammysia elliptica;
Bellerophon expansus
Aviculopecten pect:
C.
Strictopora —;
Palaeoneilo filosa;
Leden bellistriatus,
Cardiomorpha suborb
Productella lachrym
D
Aulopora tubiformis,
Spir. mesocostalis;
Orthis Tulliensis;
Encrinoidal frag.

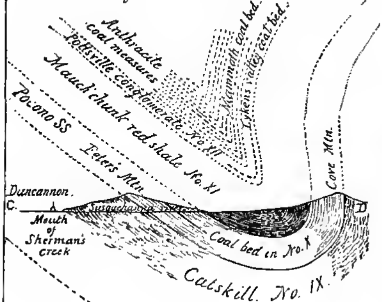
of Chemung rocks on every anticlinal sinking eastward between two anthracite coal basins; as may be seen by consulting the Colored Geological Map of the State, or the county maps in the Hand Atlas, Report X. With so great a thickness of rock beds the Chemung-Portage outcrop ridge would always be a mile wide were the dip vertical; but, as the dip is generally quite moderate a Chemung-Portage ridge varies in width from two to three miles; being however seldom more than 300′ above the Genesee outcrop valley at its foot on one side, and still less above the slight depression which often separates it from the Catskill outcrop mountain terrace on the other side. But, as the Portage rocks are sometimes sandy where the Chemung mass is almost all shale, and sometimes the Chemung is sandy and the Portage shaly, the ridges in some counties will be made more by Portage and in others more by Chemung.

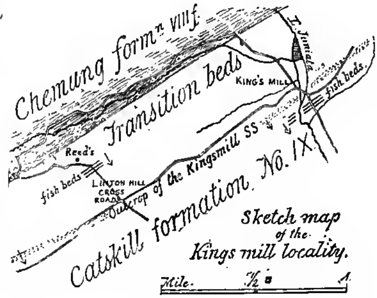
The constitution of the whole mass of the Chemung may be said to be shaly, soft, and of a drab or olive tint; so much so that on the First Survey fifty years ago we used to call it the "olive shale formation" in some districts. There is scarcely a truly hard sandstone to be found in it. Flinty strata like those so abundant in the Oneida and Medina (No. IV) are quite unknown in it anywhere. Even where it contains tolerably hard and useful bluish flagstone layers, as in Pike Co., and in Huntingdon and Bedford counties, they are generally but a few inches thick and separated by soft shales. No bed of truly Chemung iron ore is known, except those already mentioned in Bradford, Tioga and Lycoming. Nor has the formation even in its greatest development any other metallic ore, nor any coal bed; not even a true black slate which might induce the ignorant to dig for coal. Neither have its large and numerous outcrop belts, stretching from the heads of Muncy creek, Fishing creek, Wapwallopen creek and Shamokin river, northeast, to the Maryland state line, southwest, offered the slightest show of oil or gas. The whole Chemung-Portage mass east of the Allegheny mountain is absolutely barren of mineral value. But it furnishes great stretches of rather cold and not very fertile farm land, from which the timber has been

CLXXXVIII

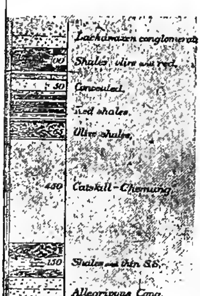
No. VIII-IX, Transition beds, Chemung-Cattskill in Perry county E.W. Claypole.

Section along the line C-D. Penn twp

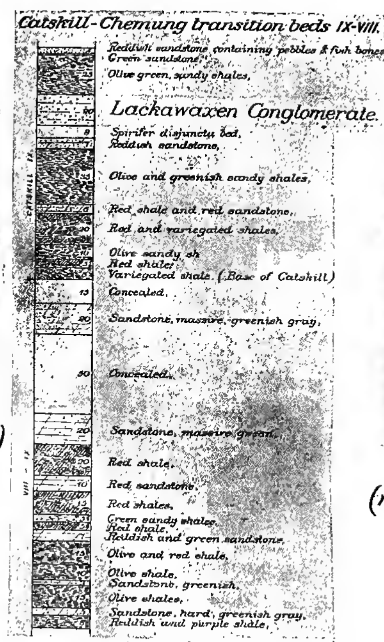




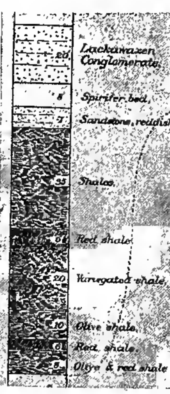
Transition beds in Huntingdon Co. I. C. White.
Upper Chemung in Bedford Co. J. J. Stevenson.



Scale 400′ : 1″ (reduced to 800′ : 1″)



Scale 60′ : 1″ (120′ : 1)



Scale 30′ : 1″ (reduced to 60′ : 1″)

cut, and most of it is under cultivation. Water springs are numerous, though never large. The surface is charmingly sculptured sideways into small short vales with little brooks descending between smoothly rounded bossy hills arranged symmetrically along a vista stretching both ways to the horizon in the direction of the outcrop lines. No one who has once learned these Chemung ridges can fail to recognize the formation in any district of Middle Pennsylvania.

The two Chemung Conglomerates.

I have already said that we have no means for identifying the two remarkable conglomerate beds of Bedford and Huntingdon counties with the First and Third oil sands of the Venango group; but if the First sand can be traced all the way from Warren Co. to Greene, a distance of 150 miles, there seems to be no reason why it should not extend a less distance to the Juniata region, and even to the North Branch Susquehanna. The Oriskany has a much more extensive outspread. The absence of the Second sand on the Juniata is not an insuperable objection, for the Second Venango sand is the variable one of the three, and actually thins out in Clarion county; and no wells have shown it coming in again eastwardly. Nor is the space of 1000′ between the two conglomerates compared with the interval of say 250′ between the First and Third Venango sands more than we should expect from the swelling of all the sand and shale formations coming eastward.

Chemung Upper Conglomerate of Stevenson. Lackawaxen Conglomerate of White.

In the Huntingdon valley this is described by Prof. White (T3, 89) as a very hard dark-gray sandstone filled with flat white and red quartz pebbles and fragments of slate, 10′ to 20′ thick; resting on rather massive greenish-gray sandstone layers (15′) on a red shale interval of 85′, which he takes for the base of his pure Catskill simply on account

CLXXXIX

No. VIII-IX, Transition beds in Perry county. Kings-mill Sandstone. E. W. Claypole.

Section across Wheatfield township.

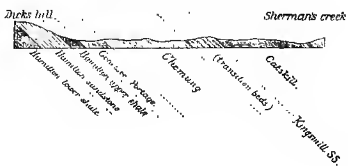
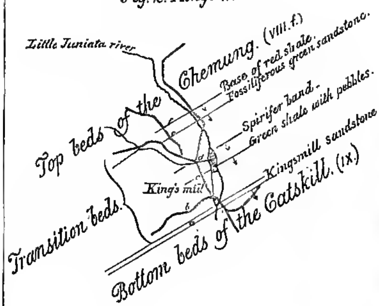
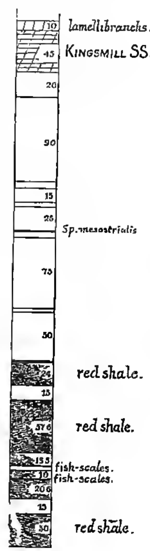


Fig. 2. King's mill.



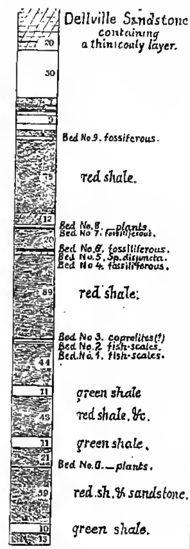
Catskill-Chemung.

Linton's Hill section

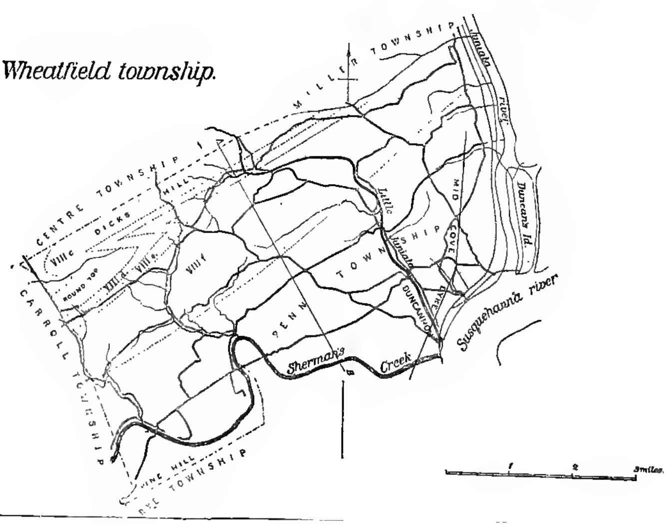


Catskill.

Kingsmill section.



Wheatfield township.



of its color, although he found Chemung shells 1000′ above it.*

In Bedford county Prof. Stevenson's upper conglomerate constitutes the back bone of Addison ridge from Brush creek south to beyond the Maryland line, and of Clear ridge from the northern edge of W Providence. Synclinal outcrops of it make Hoop-pole, Raccoon, Snyder's and Ward's ridges and the bold summit called Huff's Knob. These are continuations of its Huntingdon outcrops. On the western side of the Savage mountain anticlinal it makes a noble ridge which passes northward into Blair county as the Blue knob, and southward into Somerset county; returning S. it makes the synclinal Dry Ridge. Much of the ruggedness characteristic of the region west of Wills and Dunning mountains is due to this rock. It is rarely exposed in place within this western area of the county because its cross-cleavage joints gives the weather a good chance to break up the outcrop and scatter its blocks

*In the Shy Beaver section (T3, 163) west corner of Huntingdon, he calls it a coarse greenish sandstone, containing great quantities of round flat pebbles, some dark, others red like jasper; also *fish bones*. This is one argument for identifying it with the great *fish conglomerate* of Montour and Columbia counties (Report G7), and with the *Lackawaxen conglomerate* of Pike county (G6).—In the Coffee run section he calls it a very hard dark gray rock (10′) some portions of it filled with flat quartz pebbles. Here it makes a bold cliff, rising in long ledges far up toward the hill tops. There is an occasional *red* pebble in it, some shale fragments, and some pieces of *fish bones* (T3, 169).—In Trough creek section it rises from the bed of James creek, 100 yards above its mouth, at a dip of 35°, and makes a high ridge overlooking the Juniata; its top a massive *fish bone* conglomerate, 3′; on shaly sandstone, 5′; on massive sandstone, 7′; total 15′. Its top stratum a perfect mass of quartz pebbles and pieces of slate (but no jasper) and some *fish bones* (T3,178).—In the Patterson the rock is very massive, 20′ thick and makes a cliff along the hill; full of quartz pebbles, some 3 inches long and 1 inch thick and wide, none jaspery; *Spirifer* shells numerous; one small *Orthoceras* seen; red beds in the 700′ interval beneath; then the lowest *red* shale bed of the section; interval between conglomerates here only 860′ (T3, 185).—In the Hawn's Bridge section, a massive greenish gray sandstone (15′) with thin pebbly streaks filled with white and red pebbles broken or ground up shells, and some *fish teeth*. Several red beds come between the two conglomerates, the lowest one 600′ under the Lackawaxen (T2, 195).—Neither conglomerate shows on the Juniata below Huntingdon, except by loose blocks; but the outcrops can be traced eastward nearly the length of Henderson township and then back through the north corner of Brady.

down the hillside. Some of its layers are rich in *fossils* on Addison ridge, where it is much thicker than at Saxton, and some of its upper layers are *ferruginous.**

In Fulton county both conglomerates are thin ; but their very refractory fragments mark their lines of outcrop with such quantities of blocks that one would suppose them much thicker than they are. Here the upper conglomerate makes Clear ridge in Taylor and Dublin townships, high and continuous from the Huntingdon line south past the turnpike (east of Siluvia) and so on (as Black Oak ridge) into Maryland. In Thompson and Belfast the two conglomerates make the two crests of Timber ridge The rock in both cases varies greatly, sometimes showing only small pebbles, sometimes flat pebbles 2″ long; sometimes the whole bed is conglomerate.

In Blair county no mention is made of either conglomerate in Mr. F. Platt's long section, T, p. 14, 15. Nor are they mentioned in the Reports on Center, Clinton, Lycoming, Union, Snyder, Mifflin and Juniata.†

In Perry county Prof. Claypole describes the remarkable *King's Mill sandstone* (400′ above the lowest of the fish beds) to which I will return after giving Prof. White's account of the upper conglomerate on the North Branch Susquehanna and Delaware rivers.

In Columbia county, the long Catawissa section of Catskill rocks (given in G7, p. 57) has, No. 38, a massive sandstone containing pebbles of slate, vegetable fragments and large quantities of *fish bones*, some more than an inch in diameter. It is 40′ thick, and becomes a coarse quartz conglomerate, with immense numbers of rounded rather flat-

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* At Saxton it is only 10′ thick, but very hard. It is evident that the importance of the formation increases towards the south, just as does that of the great First Venango oil sand rock as described in the last chapter ; which is a specious argument for their identity.

† In Report, T4, on Centre co. p. 433, Prof. Ewing's notes on fossils mention incidentally the fact, that back of Unionville very large bowlders of coarse sandstone or conglomerate resembling somewhat the Oriskany are numerous. He suggests that they belong to the Portage; but more likely they have been extracted from some unreported Chemung conglomerate outcrop.

tish pebbles, the largest of them 2″ in diameter, and very large *fish bones* in considerable number opposite the Roaring Run D. L. & W. railroad water tank. Prof. White suggests its resemblance to the First Venango oil sand with fish bones and scales at Warren; and identifies it with his Lackawaxen conglomerate of Pike county.*

In Pike county, Lackawaxen township, around the village, and near the township line, 370′ above the river, a great cliff of massive pebbly rock spreads conspicuously up the stream. Its pebbles are mostly of white quartz, from a quarter of an inch to an inch and a quarter in diameter, many of them so angular as to suggest very little water wearing, embedded in a matrix of coarse greenish gray sand which makes up most of the body of the rock, in which are seen also pebbles of shale, and of the common gray sandstone of the Catskill series. The whole thickness of the stratum is 30′. †

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* Beneath it 131′ lies (No. 54) a fish bed which he makes the base of the Catskill. This interval added to 1007′ of his Transition Catskill-Chemung group (G7, p. 63) and 50′ of his topmost Chemung soft olive shales, gives a total of 1188′ between his Lackawaxen conglomerate, and a flat quartz pebble conglomerate (10′ thick) which he identifies with his Allegrippus conglomerate of Huntingdon, his Cascade conglomerate of Wayne and Susquehanna, and Sherwood's Falls Creek conglomerat in Bradford county, the Venango Third oil sand (G7, p. 71).—The matrix of the fish conglomerate is a coarse greenish gray sand. This is the only place in the district where Prof. White saw a conglomerate at this geological horizon; but in the next township east (Montour) a very coarse massive sandstone, with large fish-bones in it, makes a broad rocky platform both sides of Roaring. The Rocky Run outcrop makes a great bare platform of massive rock on both sides of the run at the water tank, with vertical cliffs walling in the water course, the dip being 35° to 40°, S. 10° E. (G7, p. 303).—Considering the solitary apparition of this Rocky Run conglomerate, as we may call it, and the large number of fish beds known to exist in Chemung and Catskill series, it seems to me a little hazardous to adopt unhesitatingly its identity with other fish bed conglomerates in distant counties of the state. We must leave to future explorers the task of proving or disproving such facts.

G6, p. 156. † The cliffs overhang the Lackawaxen river for four miles up to Rowland's where they measure 60′, in massive beds from 5 to 10 feet thick, full of angular quartz pebbles; and near the center of the mass a layer of very large pebbles with many pieces of shale. A mile above Rowland's another great cliff (60′) near the summit of the hill overlies the conglomerate 75′ to 100′. The local character of this pudding stone deposit is shown by the fact that at Millville, 4 miles above Millville it has so changed into a com-

Allegrippus or Chemung lower conglomerate.

In Huntingdon county the great central mass of Chemung strata 1500′ or 1600′ thick are rather heavy gray sandstone beds making the higher valley hill ranges, like the Allegrippus ridge southwest of the Juniata, and extending through Bedford county into Maryland, as mentioned earlier in this chapter. The 1000′ or 1100′ underlying mass of shales (called *Portage* here) make wide and level slopes of farming land with a yellowish poor soil; but as the lower part of this (Portage) shale mass is rather harder or more sandy than the rest its surface falls off suddenly into the Genesee and upper Hamilton valley.*

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mon sandstone that it cannot be recognized in the steep hill sides. But at Kimble's station, 4 miles further up, it resumes its massive character and makes a bold promontory among which the river flows at the Narrows, where vertical walls only 40′ apart turns the river into a dangerous mill race for rafts and canoes; here it is 60′ thick. Here a local roll carries it under and when it emerges again it cannot be distinguished from the other greenish grey sandstones of the series. At Kimbles it is well exposed in the deep railway cut, as quite pebby, dark steel grey, containing many small pieces of bluish green slate. The base of the conglomerate is here 55′ above water; the hillside 465′ high, and the extensive flagstone quarries at various elevations from base to summit, the flagstone beds being from 2 to 5 inches thick, grayish green, with smooth upper and under surfaces, and affording lengths and widths of any desirable size. But they seem to be split by the weather; for when quarried back into the hill they form strata from one to three feet thick which cannot be split smoothly into thinner layers (G6, p. 160).—In the Pine Grove slate section is a very massive sandstone, 75′ thick, making a great cliff, in the talus at the foot of which are many blocks with small pebbles.—Three miles above Pinegrove, on Mast Hope creek, are great blocks of pebble sandstone, opposite a cliff 50′ high running along the hill sides. Half a mile further up the stream a 45 cliff of rocks, with large white angular quartz pebbles and chips of bluish shale, may be the Lackawaxen conglomerate brought up by a roll, or may be some higher stratum simulating it (G6, p. 163). Surely the identity of such exhibitions in such a series of sandstone strata must be very questionable. It is noteworthy that no fish remains are mentioned.

*Thus Huntingdon is built on a Hamilton plain; vertical bluffs of Portage lower sandstone overlook Muddy and Standing Stone creeks; and are in turn overlooked by Chemung sandstone high ground. The river gaps the Portage bluffs, which are called Stone ridge east, and Piney ridge west of the river. The Chemung high ground west of the river is Allegrippus ridge, the crest of which is made by Stevenson's Lower Chemung conglomerate. It must be kept in view that Stevenson includes in his Chemung 1750′ of White's lowest Catskill and Chemung-Catskill transition or passage beds; thus both conglomerates, although 1000′ apart, fall into his Chemung formation.

Allegrippus ridge has a continuous crest-outcrop of the lower conglomerate, which, like the upper one, is largely composed of white quartz pebbles in a matrix of whitish sand. But it is rarely more than five feet (5′) thick; and yet it makes a bolder show than its rival on the opposite hill; for, where the rock itself does not project from the surface a straight line of piled up fragments traverses the fields of shale. Every road crossing Allegrippus ridge as far as the Bedford line shows it plainly; and, as has been already said, in Bedford and Fulton counties the Chemung ridges are crested with it in a like, or even in a superior manner.*

Not a single *bed of red rock* has been seen by White in Huntingdon or by Stevenson in Bedford and Fulton in the mass of Chemung and Portage strata which is 2500′ thick from 150′ over this conglomerate down to the Genesee formation; nor in fact, in all the mass of 5350′ of strata down to the Salina formation.

In Columbia Co., Hemlock township, in Prof. White's Fishing creek section (G7, p. 225) No. 9 is a greyish sandstone with some flat quartz pebbles. 10′ thick, lying 50′ beneath the lowest observed red shale bed, assumed as a convenient base for his *Chemung-Catskill transition series.* He reports it widely distributed in his Montour Ridge district; and conjectures that it is perhaps identical with the Cascade or Falls creek conglomerate of the New York state line country (G7, p. 71); but afterwards he considered it identifiable with the Allegrippus conglomerate of Huntingdon

*On Shy Beaver this curious solid layer of large flat pebbles is only eight inches (8″) thick where ti projects from the hillside. It lies only 900′ below the upper conglomerate. Ou Coffee run its place is marked by fragments of conglomerate 1000′ below the upper. In Penn township its boulders (none of them however more than a foot large), filled with snow white quartz pebbles in a matrix of coarse gray sand, make so broad a belt that it is almost impossible to realize the fact that it is all the product of only 5′ of solid rock. But the fact is they have remained accumulating on a surface of shale outcrops which for ages ha been washed away by the rainfall and steadily lowered towards sea level. These rocks contain enough iron to make them weather red or reddish, but only skin deep; this however gives a destinctive reddish streak along the landscape, as if the outcrop line was red shale or sandstone. The Haun's Bridge outcrop of 5′ is bold and has covered the ground with blocks, in some of which lie *fossil shells.*

county. But it seems to contain no fossils, and has nothing but its place in the series to support its claim ; and we know too well by the lower and upper oil sands what such a claim should be valued at.

Fall Creek conglomerate in Bradford Co.

In Sherwood's section (G, p. 67) No. 7 is a hard quartzose white very false bedded sandstone and conglomerate, 15′ to 20′ thick, in the Upper Chemung formation in the south part of Ridgebury county half way between Middletown and Smethfield Summit, where ignorant people were seduced into the throwing away of much money in mining for silver. The same rock seems to strew the ground with great blocks at Mitchell's steam mill in his Cowanesque RR. section (p. 90). It contains no fossils. Mr. Sherwood's claim to have identified this rock through the southern counties of New York with the Venango Third oil sand rock is hardly worth consideration. Prof. White took the pains to identify it with his massive yellowish white sandstone No. 6 of his Cascade section in northern Susquehanna Co. 25′ thick, (G5, p. 98). He found it in several intermediate places, and subscribed to Mr. Sherwood's identification of it with the Panama conglomerate of western New York and the Third Venango oil sand (G5, 100).*

*On Cascade creek, where the Erie RR. crosses, it makes vertical cliffs, is very coarse, contains immense quantities of carbonized branches and limbs of fossil trees, so macerated that not even their *genera* much less species can be determined ; its lower layers full of *Spirifers* and *Rhynchonellas*, all of Chemung types ; and it is so full of pyrites that its face is frosted with yellowish copperas. It lies about 350′ beneath the New Milford lower sandstone, or as he says 150′ beneath the top of the Chemung, which however is his own classification. He adds that Sherwood's Fall creek rock lies at 325′ below the N. M. L. S. (G5, p. 100). The Cascade layers hold *Rhynchonella contracta*, a *Pterinea*, *Productella boydii*, *Spirifera disjuncta*, and other less numerous shells (G6, p. 76). It is observable that no fish remains are mentioned ; and the distance is too great from Central Pennsylvania to make it at all probable that this local sandstone can be identified with either of the conglomerates of Huntingdon county ; especially since it was not recognized in Pike and Monroe counties.

The two conglomerates in Perry Co.

The Chemung formation on the Lower Juniata is confined by Prof. Claypole to 3300* feet of olive shales and thin bedded fine grained sandstones, entirely devoid of red rocks except a few intruding layers towards the top of the mass, which are apparently local and irregular.

This mass of olive grey is capped by yellow shales; and above this lies the huge mass of Catskill red shales and red sandstones, 6000′ thick, which make the Cove and Buffalo mountain sides and foothill slopes (F2, p. 71).

This seems to be a simple statement. But there are difficulties. For between the Chemung and Catskill masses, or rather belonging to both, is an indefinite set of alternations of red and grey shales corresponding to White's Chemung-Catskill *transition* series between the two conglomerates, culminating in importance in Saville township i. e. in the direction of the Huntingdon county. This Claypole calls (page 70) *Upper Chemung;* agreeing thus substantially with Stevenson's classification in Bedford county; except that the latter carries the Chemung much higher into the Catskill region of the column, greatly increasing the thickness of the Chemung mass, and correspondingly diminishing that of the Catskill mass.

In this middle ground are two sandstones and four *fish beds* in Perry county. But whether they represent the two conglomerates of Huntingdon and Bedford is very doubt-

*This is his measurment at Newport on the Juniata. But at Rockport on the Susquehanna, 4 miles above Harrisburg, and only 15 miles S. E. of Newport, the whole Chemung, Portage, and Genesee taken together measures only 1100′. Prof. Claypole ascribes this loss of more than 2200′ of Chemung measures to a rapid thinning out of the deposits towards some dry land in the south. But I have given in Vol. 1 my reasons for disbelieving the existence of such dry land, and for ascribing the extraordinary Susquehanna Water Gap section anomaly to the sweezing pressure and sliding movement of the great overturn, causing a disappearauce of the formations. In Dauphin, Schuylkill, Carbon, Monroe and Pike counties the Chemung is enormously thick, and even thicker than at Newport. Prof. Claypole confesses that he could obtain no measurements in the disturbed country between Newport and Rockville; nor any proof of the thinning of the formation westward towards Fulton county (F2, p. 71).

ful, in fact improbable ; and no direct connection between them has been established by continuous outcrop-tracing across Juniata county.

Dellville green sandstone of Perry county.

The hard lower beds of the Catskill mass make a hillside barrier to Sherman's creek (in Wheatland township, past Dellville), reflecting it whenever it makes a northward excursion. Two of these beds, with a coaly layer between them, the whole 20′ thick, make a well defined geological horizon in the midst of the monstrous pile of red shales and red sandstones which is recognizable over a considerable area of country. It is well shown at the foot bridge a mile west of Dellville, at Dellville, and on the Juniata near Kings mill, where its layer of plant-remains almost makes a thin *coal seam.*

As no Chemung fossils were seen by Mr. Claypole above this Dellville sandstone he adopts it as a convenient base plane for the great red Catskill mass, and a top plane for the debatable middle ground, which he measures at about 1300′, down to the top of the olive shale Chemung mass (F3, p. 394).

By uniting two sections made near Kings Mill and Linton Hill, and estimating at 200′ or 300′ the interval between the bottom rock exposure of the one and top rock exposure of the other, the horizons of the sandstones and fish beds of the Middle ground, or Transition series, Chemung-Catskill, are made sufficiently clear, at least in the Lower Juniata region. (Sections F3, p. 166).

DELLVILLE GREEN SANDSTONE, with coaly layers, . .		20½′
Concealed, ...		50
Red shale and sandstone, ...	7	
Green shale, ...	1¾	
Red sandstone and shale, ...	3½	
Green shale, ...	1	
Red sandstone, ...	1	
Green shale, ...	4½	
Red sandstone, ...	0½	
Green sandstone, ...	9	
(9) Green shale, with *fossils*, ...	5	
Red sandstone and shale, ...	7½	
Green shale, ...	4	47

Red shales, with one thin green bed,		78
Red sandstone in thin beds,	12	
(8) Green sandstone, hard thin beds,	2½	
Green sandstone with *plants*,	0½	
Red shale,	0¾	
(7) Greenish yellow shales, *fossils*,	2⅓	18
Red shale,		20
(6) Green shales, *fossils*,	} 1	
(5) *Lime-shale, Spirifera disjuncta*,		
(4) *Blue limestone, fossils*,		
Green sandy bed,	0½	
Red blotched sandstone,	4	
Red shales, thin red sandstones, some slightly micaceous,	89	94
(3) Green sandstone with *coprolites?*	0¼	
Red sandstone,	3	
(2) *Fish scale bed*,	thin	
Red micaceous sandstone,	2	
(1) *Fish scale bed*,	thin	
Red shales and sandstones,	44	
Green shales,	11	
Red shales and shalestones, green beds,	43	
Green sandy shales,	11	
Red shales and shalestones,	21	135
(0) *Plant bed*, yellow sand,	0½	
Red shales and shalestones,	59	
Green shalestone,	10	
Red sandy shale with solid thin beds,	13	82
Total of upper section,		553

Interval between sections estimated at 200 or 300 feet, making the vertical columnar distance from the Dellville sandstone down to the Kings Mill sandstone 733 or 833 feet.

KINGS MILL SANDSTONE,	10	
Sandstone, brown, thin beds,	45	55
Yellow shales and thin brown sandstone,	116	
Green shales, weathering yellowish,	7½	
Brown shale,	15	
Greenish yellow shale,	5	
Brown shalestone,	1	
Brown rusty bed, *Spir. mesostrialis*,	0⅓	
Brown shale,	6⅓	
Yellow shale, mostly concealed,	75	
Brown soft sandstone,	5	
Yellow shale,	50	281
Red shale,	1¼	
Yellow shale,	1¼	
Red shale,	24	
Yellow shale,	15	

Red shale,	71	
Yellow shale,	$3\frac{1}{2}$	116
Fish scale bed, red sandy slate,	thin	
Red shale,	10	
Fish scale bed, solid ledge,	$0\frac{1}{4}$	
Red shale,	$20\frac{1}{2}$	
Yellow shale,	16	
Red shale, lowest in the series,	50	106
Total of both sections and interval,	1320 to 1420	

Kings Mill sandstone of Perry county.

The outcrops of this remarkable white sandstone deposit may be traced to and fro across Perry county, beneath which it must spread, continuously, at a geological horizon about 500′ above the top limit of the olive shale mass of the Chemung. At Linton's hill its layers stand out almost vertical, apparently between 12′ and 20′ thick, holding innumerable fossils located in colonies, so that sometimes one side of a slab is a clean smooth sandstone, and the other side of it a conglomerate of *flat quartz pebbles* and *casts of shells* (*Schizodus rhombeus*, etc., mostly lamellibranchs). A mile further east (2 m. N. W. of Duncannon) near Kings Mill the fields are strewn with its masses honeycombed with casts. It makes a conspicuous ridge near Shermansdale mills, where it holds large lamellibranch shell-casts, many of them filled with red, purple or black oxide of iron. In the northern townships it makes the backbone of the western Middle Ridge, and returns along the S. side of Hominy Ridge. Between the rivers it makes two parallel outcrops along Wild Cat valley; and a continuous low stony ridge across Watts township. But fossils are not plentiful in its northern outcrops. The multitudes of them in the Kings Mill outcrop are all broken and drifted; seldom can two valves in contact be found. They look like sheets of limited extent piled up by the waves on a shore. Very different are those in the overlying 500′ of shales; for these show that the animals lived and died where they are seen now lying in the rocks, the shells perfect, both valves together, and the internal spiral often well shown: but their small size indicates unfavorable life conditions; in fact the approach of a Catskill age the waters of which were charged with sulphate of iron, or some other noxious element.

The Kings Mill fish beds and plant beds.

The highest two fish beds in the section are but two feet apart. They are solid layers of scales, mostly broken, and very difficult to extract from the crumbling stone. They belong to armored fishes of the genus *Holoptychius* or *Bothriolepis*, and it is not certain that they do not all belong to one species. Three feet above them in in a green sandy coarse shale, lie numerous small nodules or concretions, which were supposed to be fish dung (*coprolites*) but Mr. McCreath's analysis of them obtained a very small percentage of phosphoric acid. The fossiliferous layers in the overlying rocks up to the Dellville sandstone contain immense numbers of a small crustacean (genus *Beyrichia*) showing white on the weathered surface, but very difficult to see in the hard blue limestone core of the layers, which weathers to a soft rusty mass, full also of brachiopod and lamellibranch shells, many of them well preserved, and among them the characteristic Chemung species *Spirifera disjuncta.* Layer No. (6) green shale is full of lamellibranchs. No. (7) has many small indistinct shells.

The two lower fish beds, 10′ apart, are also layers of fish scales. No fish beds were found in the Middle Ground section in Wheatland township. But at one place well rounded oval pebbles in green shale, which Mr. Claypole thinks indicative of shallow water; to which he adds the evidence of great quantities of vegetable remains, or *plant rags*, whick blacken the surfaces of some of the sandstone and sandy shale layers of the section, extending over acres and square. miles. They must be remains of *land plants* floated out to sea. (F3, p. 393).

Chemung fossils in Perry county.

The olive shales afforded to Prof. Claypole's researches *Productella hirsuta*, *Cyrtina hamiltonensis*, *Strophodonta perplana*, *Orthis impressa*, *Atrypa reticularis*, *Spirifera mesostrialis* and *mesocostalis*, *Leiorhynchus mesocostale*, *Chonetes logani*. Also the lamellibranchs *Palæoneilo filosa* and *constricta*, *Modiomorpha concentrica* and *subalata*, *Eodon bellistriatus*, *Grammyias elliptica*. Their fragmentary condition makes collection difficult. Good exposures are not numerous, and the Chemung outcrops are wooded. The numerous small anticlinal folds have distorted and broken the fossils. (F3, preface, p. 14).

Chemung-Catskill fossils in Perry co.

In this middle ground of transition rocks the brachiopods diminish in number in proportion to the lamellibranchs; and the fossilerous layers seem to lie high up in the series, between the red shale beds containing *fish scales* and the Dillville sandstone, the assumed base of the great red shale and red sandstone Catskill mass, which is almost entirely barren of animal fossil forms of any kind.

Claypole's list contains; *Spirifera disjuncta* and *mesostrialis;* the lamellibranchs *Sanguinolites undatus*, *Goniophora chemungensis*, *Modiola metella*, *Schizodus oblatus*, *chemungensis* (?) and *rhombeus*, *Lyriopecten priamus*, *Actinopteria zeta*, *Cardiomorpha rotunda;* the gasteropod *Bellerophon maera* (or a variety); and the fishes *Holoptychius americanus* and *Bothriolepis taylori*. Other undefined form occurs in these beds; and many of those identified show some variation from published figures and descriptions, probably the result of conditions of life for the most part unfavorable (F3, preface. p. 15).

Chemung-Catskill fossils in Bedford co.

Prof. Stevenson's section at Saxton is as follows (T2, p. 77) :—

1.	Red to yellow shales with thin sandstones,	418
2.	*Upper conglomerate* (*Lackawaxen*),	10
3.	Shale,	30
4.	Sandstone,	12
5.	Shale and sandstone,	30
6.	Concealed, estimated,	450
7.	Shales and flaggy sandstones,	101
8.	Sandstones and thin shales,	76
9.	Shales with flagstones,	30
10.	Sandstone,	16
11.	Shale, ill exposed,	185
12.	Sandstone,	35

13. Shales,	40
14. *Lower conglomerate (Allegrippus),*	8
15. Shales with flaggy sandstones,	115
16. Concealed, estimated,	310
Portage formation,	1100

In this section *Spirifera disjuncta* is found at the very top (in No. 1); but no fossils are seen in 200′ or 300′ still higher; and in fact all life seems to cease above this, for not a single shell was noticed by Prof. Stevenson in the whole Catskill mass above, except one *Amnigera catskillensis* from one of its highest beds on Wills creek (T2, p. 75). The beds above the Upper conglomerate are at Saxton more or less fossiliferous throughout. *Streptorhynchus chemungense* and a shell closely allied to *Orthis tioga* occur in the highest bed, along with *Spirifera disjuncta.* Sandstone flags are full of Chemung lamellibranch shells. Beneath the Lower conglomerate a bed was found containing *Ambocœlia*, *Rhynchonella*, *Productus*, and *Streptorhynchus.* (F.2, p. 79).*

* In Claypole's collections, north of Liverpool, Bedford Co., Cat. 000, p. 135, etc., are recorded also *Leiorhynchus globuliforme*, *Cyrtina hamiltonensis*.—At N. Bloomfield, *Aulopora tubœformis*, *Orthis carinata*, *Palœoneilo filosa*, *Sanquinolites ventricosa* (*p. 135*).—At Newport, *Lyriopecten macronotus*, *Cryptonelta eudora*, *Lepidodendron chemungense* (?), *Stictopora meeki* (p. 133).—At N. Bloomfield, *Leptœna rugosa*, *Chœtetes*, *Meristelta bella* (p. 131).—At Newport in VIII-IX, *Meristella lœvis*, *Rennsellœria mutabilis*. *Orthoceras longocameratum*, *Chœtetes abruptus*, *Beyrichia granulata*, *Tentaculites gyracanthus* and *Beyrichia notata* (both on one slab), a *Calymene*, *Lepidocystites gebhardi*, a *Stromatopora* (or *Astrocerium*), a *Trematospira* (or *Cladopora*), *Discina ampla*, *Strophomena woolworthana* (p. 129). At Shermandale mill, in VIII-IX, *Lingula regia* with plant remains (p. 143).—At Bloomsburg in Columbia Co. from VIII g, *Chonetes lepidus*, *Modiolopsis concentrica*, *Streptelasma rectum*, *Leiopteria dekayi*, *Actinoptera birostrata*, *Phacops rana*, *Atrypa aspera*, *Spirifera fimbriata*, *Orthis vanuxemi*, *Chonetes setigerus* (p. 143, 144).—S. of New Bloomfield, Perry Co. from VIII-IX. *Schizodus quadrangularis*, *Modiomorpha subalata*, *Actinodesma birostratum*, *Tentaculites spicula*, *Productella lachrymosa*, *Limoptera macroptera*, *Modiomorpha catskillensis* (p. 139).—At Kings mill, VIII g and IX, *Leptodesma potens*, *Cyclonema concinna* (p. 142).—Road to Carlisle, VIII g, *Orthoceras demas* (p. 143). Bloomsburg, VIII g, *Rhynchonella emma*, (p. 149).—Bloomsburg, Col. Co. Stonybrook beds, White's top of VIII g. *Coleolus acicula*, *Palœoneilo brevis*, *Nuculites oblongatus*, *Nucula bellistriata* (p. 152).—King's Mill, at top of VIII, *Leda rostellata*, *Palœoneilo barrisi* (p. 154).—At Dellville, of VIIIg, *Conularia continens*, a crinoid, a *Lichenalio?* (p. 156).—Duncan's island, VIII-IX, *Schizodus cuneus* (p. 165).—All these are in addition to those given in Claypole's Report F3, above, and they occur at various places with the species given above.

White's Stony Brook beds, top of VIIIg.

Along Little Fishing creek, Hemlock township, Columbia county, Prof. White made the following section, starting from the *lowest red bed*, which he took as the *base* of his Transition VIII–IX group (G7, p. 71) :—

Lowest red bed of VIII–IX group,	—
Olive soft shales (*Upper Chemung*),	50
Conglomerate (*Allegrippus*),	10
Olive shales, rather soft,	200
Flags, hard, greenish, sandy,	150
Stony Brook Shales, fossiliferous,	75
Shales, very hard, sandy, gray, bluish and dark olive (*Lower Chemung*),	1875
Genesee shale,	—

Everywhere in this region of Northumberland, Montour, Columbia and Luzerne the Chemung can be divided into two series quite different from each other in lithological character, taking the bottom of the Stony Brook beds as the dividing plane between them.

The *upper* division 500′ or 600′ thick consists largely of olive green shale crumbling under the weather into small chips and splinters which soon turn to clay. The *lower* division has in many places a grayish white rock with small flattish quartz pebbles scattered through it (Allegrippus conglomerate) ; then shales and flags ; then the *Stony Brook Shales*, so remarkable for its abundance of fossils, finely exposed on the roadside at the mouth of Stony Brook 3 miles N. of Bloomsburg.

The fossils are: *Leiorhynchus mesocostale*, *Spirifera disjuncta* and *mesocostalis*, *Productella hirsuta*, *Chonetes setigerus*, *Strophodonta perplana*, v. *nervosa*, *Orthis tioga*, *Atrypa recticularis*, *Cleidophorus oblongus ?*, *Orthonota siliquoidea* (or near it), *Nucula corbuliformis*.*

* Two miles from Danville, opposite the canal locks, the same beds appear and have, in addition to the above, *Productella* v. *rectispina*, *Leiorhynchus globuliforme* and *mesocostale*, *Streptorhynchus chemungense*, *Bellerophon maera*, *Goniatites discoidea?*—*Spirifera disjuncta* (with abruptly sharp pointed wings), *S. mesocostatis*, *Productella hersuta* and *Leiorhynchus mesocostale* are associated together in countless multitudes here and in all the outcrops of the Stony Brook group of beds. Hamilton species are comparatively absent.

We may regard this group as typical Chemung. As far west as Crawford and Erie counties beds filled with substantially the same fossils are found lying at 50′ to 150′ below the Venango Third Oil Sand (G7, p. 72).

The Lower Chemung (and Portage) mass of about 1900 feet, from the Stony Brook beds down to the Genesee, are a monotonous succession of dark gray and dark olive green and brown sandstones and shaly sands, a mass making high ridges and bold waterside cliffs, throwing down splintery fragments 4 to 6 inches long. The following section along the North Branch Susquehanna RR. (F7, p. 66, Fig. 13) will give the prevalent fossils at their horizons,

Stony Brook beds, as above,	50
Spirifer bed, 6 inches thick,	—
Olive, gray, sandy; cliffs; few fossils,	200
Spirifer disjuncta bed, 6 inches,	—
Shales, greenish brown,	20
Shaly standstones, dark olive,	60
Sandstones, dark gray, olive, cliffs, crinoidal fragments near bottom,	100
Sandy olive beds, *S. mesostrialis* at top, *Stictopora* below middle,	50
Sandy, hard, dark gray, with *Stictopora and crinoidal stems* every 3 or 4 feet,	65
Stictopora bed, 6 inches,	
Hard olive gray beds,	15
Sandy layers full of *Stic.* and *Crin.*,	45
Crinoidal layer, 6 inches,	—
Sandy, olive layers,	15
Stictopora bed 6 inches,	—
Hard olive gray beds,	25
Stictopora and *Sp. disjuncta* bed, 6″,	—
Massive dark olive and gray,	130
Spirifer bed,	1
Very hard, dark green and bluish olive,	125
Leiorhynchus mesocostale, Spirifera disj. and *mesocos., Orthis impressa. Stroph. cayuta, perplana v. newosa, Prod. hirsuta, Gram. elliptica, Aviculo-pecten pectiniformis, Mod. metella, Nucula corbuliformis, Bell. expansus, Stictopora* ——? and several undetermined forms,	1
Sandy, bluish gray,	20
Spirifer bed, 6 inches,	—
Dark olive sandstones and slates,	100
Sperifer bed,	2
Bluish shales,	5
Spirifer disj. and *mesostrialis*,	2
Hard dark olive sandy shales,	100

Sandy beds holding at various horizons: *Eodon bell.*, *Cardiomorpha suborb.*, *Pal. filosa*, *Nucula lineolata* and two other species undetermined, *Chon. lepidus*, *Sp. mesocost.* and *mesostrialis*, *Prod. lachrymosa? Stictopora* and other forms undetermined, ...	125
Hard sandy gray beds; no fossils, ...	300
Dark gray, with *Leiorhynchus mesocostale*, ...	60
Olive brown sandy shales, with *Aulopora tubiformis*, *Orthis tulliensis*, *Chonetes setigerus*, *Nucula lineolata*, *Palæoneilo filosa*, *Pteronites chemungensis*, *Leiorhynchus mesocostale*, *Sp. mesocostalis*, and crinoidal fragments, . . .	20
Olive and brown hard sandy beds ; no fossils, . . .	175
Dark blue shale sandstone, with a limy layer at base, overlying the Genesee shale, ...	25
Total thickness of Chemung in this section 13,	2300
Total thickness in section 12, one mile distant, . .	2443

Chapter CVI.

No. IX. The Catskill Formation.

This uppermost division of the Devonian system was named after the lofty mass of mountain land which rivets the admiring gaze of travellers on the Hudson river after they have passed the Highlands and are nearing Poughkeepsie, on their way to Albany. At Catskill village they are opposite the center of the eastern face of the mountains; and if they land here, a ride of 20 miles westward will carry them up to summer resorts 2000 and 3000 feet above the tidal river; and to still loftier summits, from which the view extends to the Highlands of Massachusetts on the eastern horizon. It is a lofty table-land of red and grey sandstone and red and grey shale strata, lying nearly flat, but turning up along the southern wall with dips of 10°; 20° or 30° northwestward; and here supporting remnants of still higher grey sandstone deposits, constituting isolated peaks, some of which reach heights of 4500 feet above tide. These were once called the *Upper Gray Catskill* rocks, but are now named in the Reports of the Pennsylvania Survey *Pocono No. X.* A new name was necessary to designate a formation preserved to the extent of only about 1000 feet in these New York peaks, but forming mountains in Pennsylvania with a thickness of 3000 feet. Moreover, with this Pocono gray sandstone formation begins the Carboniferous System, since it contains our lowest and oldest coal beds; as will appear in the opening chapters of the next volume of this report.

The southeastern wall of the Catskill table-land is broken by descending ravines which deliver the rainfall by the Esopus into the Hudson. Its eastern face in like manner gives outlet to the waters of the Katterskill and other torrents. Through its northern edge flow down the head branches of the Scoharie into the Mohawk; the rest of its drainage descends into the cross cut trench of the Delaware.

Towards this eastern border of Wayne and Pike county in Pennsylvania the whole New York Catskill strata slowly fall, with an almost imperceptible dip, westward ; but not as a perfect plane. For the gorge of the Delaware exhibits at least three broad and exceedingly gentle anticlinal waves, by reason of which the mountain land say only 15 miles wide on the Hudson is spread out to a width of 40 miles on the Delaware. These gentle undulations are the gradual expiration of the north east ends of the comparatively narrow and steep rock-waves which separate the Anthracite coal fields from each other ; as shown upon the map of the Anthracite region and State Map.

The Pocono plateau.

After crossing the Delaware river into Pennsylvania the Catskill mountain plateau spreads westward as a high table land over northern Pike, Monroe and Carbon counties to the Lehigh river. Its southern edge is a wall built up in steps of nearly horizontal but gently northward dipping massive red standstone outcrops separated by red shales ; the whole surmounted with a coping of gray conglomerate strata which forms an early level upland wilderness called in old times the Great Beech Woods, or the Shades of Death. Its rainfall is drained off by the head waters of the Lehigh,.in a great curve, first north and northwestward, then westward, and finally southward from Whitehaven to Mauch Chunk, down through a long ravine or trench, between high vertical cliffs of red rocks, made picturesque by oxbow curves.

This southern edge of the plateau is called the Pocono mountain in Monroe and the Pohopoco mountain in Carbon county. It looks across the lower hill country bordering the Delaware river to the long crest of the Schangunk mountain, which it far overtops and overlooks into the northern counties of New Jersey.*

* This superb landscape can be enjoyed by the traveller who pursues the old North and South turnpike from the Wind Gap and ascends the steep wall of the Pocono mountain, on his way to Scranton. The Schawangunk

Pocono Knob.

Pocono Knob, in Monroe, is a bold promontory projecting eastward from the plateau, the edge of which recedes northward some miles and then resumes its northeast run into Pike, its front staircase of rock being ravined by Broadhead, Marshall and Bushkill creeks. Pocono Knob. is isolated thus on account of a broad gentle anticlinal arch passing behind or north of it.

Big Creek mountain in Carbon is a similar but much longer and bolder promontory, pointing also eastward, produced by the long Stroudsburg anticlinal which reaches and crosses the Lehigh river 5 miles above Mauch Chunk, the arch of Catskill rocks being seen in the wall of the gorge entering the Nesquehoning mountain west of the river.

Mauch Chunk mountain is a continuation of Big Creek mountain westward across the Lehigh 2 miles below Mauch Chunk; it then runs in a straight line S. 60° W. to the Little Schuylkill river below Tamaqua. Here the two zigzags of *Wild Cat mountain*, produced by the Lehighton anticlinal, project another promontory looking east.

Second mountain now carries forward the Catskill outcrop in a straight course S. 62° W. to the Schuylkill 3 miles below Pottsville,—to the Swatara 1 mile above Pinegrove, —to the Susquehanna 8 miles above Harrisburg,—into Perry county, where it is known as *Cove mountain.* It returns to the river as *Fourth* or *Peters' mountain* opposite

or Kittatinny crest is recorded by White at three points as 1350 (Bangor road), 1450 (Wind Gap), 1540 (Kunkletown road) feet above tide; but the D. L. and W. railroad grade where it crosses the Pocono plateau (going north) at Pocono Station, Tobyhanna and Gouldsboro, reads 1840, 1932 and 1890; and the two intermediate summits 1955 and 1970 A. T. Even Elich's Pond in Pike county lies at 1754 A. T.—See Prof. White's excellent description of the Pocono mountain plateau in his Report G6, p. 8, where he says that its general elevation for a width of 15 miles varies from 1800′ to 2000′; the water courses sunk 100′ to 200′ below; and the knobs and patches of uneroded upper rocks (sandstones and conglomerate) rising 100′ to 200′ above the general surface. The map of Pike county shows by its coloring that these Pocono patches and knobs are confined exclusively to its western corner, Green township. But Monroe county retains a continuous covering of Pocono strata over the northwestern third of its area, Coolbaugh, Tobyhanna, and Tunkhannock townships.

Duncan's island. Thence running east through northern Dauphin it returns to and recrosses the Susquehanna 2 miles below Millersburg,—makes another Cove in Perry county and returns to the river as *Buffalo mountain*,—runs on east as *Mohontongo mountain* to the extreme head of Mohontongo creek,—then returns west as *Mahanoy mountain* through Northumberland to the Susquehanna at the mouth of Mahanoy creek,—immediately turns east again as *Little mountain*, crosses the Shamokin at Mt. Union, and keeps on to the N. W. corner of Schuylkill county,—then returns as *Catawissa mountain*, northwestward, in a series of short zigzags to the North Branch at Catawissa.

As *Nescopec mountain* it makes a long stretch eastward across Columbia into Luzerne county,—turns the head of the Wapwallopen creek, and runs back as *Wyoming mountain*, perfectly straight and nearly due west, across the river, and across Columbia county, to the superb promontory in W. Hemlock township, Montour county.

From this knob it takes a new departure as *Schickshinny mountain* in a straight line N. 60° E. past Schickshinny gap to the North Branch 6 miles above Pittston; and so onward as *Elk mountain* (curving to N. 45° E.) across Lackawanna county to the northeastern corner, and on north just inside the west line of Wayne to Mount Ararat.

In this northern region the Catskill formation lies so flat as to cover the surface of all northern Pike, all Wayne, most of Susquehanna and Bradford, the N. W. third of Lackawanna, and the space between Schickshinny and Great North (Allegheny) mountains in Luzerne counties.*

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* In Wyoming, Sullivan, Lycoming, Tioga, Potter and McKean, the steep and craggy sides of all the valleys and ravines exhibit the basset edges of the formation; and therefore it is necessary to consult the colored State Map to learn where it occupies the present surface. The first map in the Hand Atlas, X, 1885, is colored bright red so as to show the formation. The broad spaces so colored are districts where the strata lie nearly flat; the long red zigzag lines show the outcrops where the dip is steep, vertical, or overturned.

The Great North or Allegheny mountain.

As the flat strata in Pike and Monroe crop out along the front face of the Pocono plateau in a stair-case wall, so the flat strata in Wyoming and Lycoming crop out along the similar front face of the Great North mountain plateau in a wall which runs west to a high promontory looking towards the North Branch Susquehanna at Muncy. This face wall returns east to the head of Muncy creek, and then takes its long curved course, as the *Allegheny mountain escarpment* through Lycoming, Center, Clinton, Blair and Bedford counties into Maryland and Virginia; and out through this high wall of rocks break the majestic ravines of the Loyalsock, the Lycoming, Pine creek, the Susquehanna west branch, and Beech creek, just as from the Catskill-Pocono plateau break out the mighty trenches of the Delaware and Lehigh rivers.

The double crested Second mountain.

Far different are the circumstances connected with the narrow zigzag outcrops which traverse Carbon, Schuylkill, Dauphin, Perry, Northumberland, Columbia and Luzerne counties. From the Lehigh to the Schuylkill rivers, the Catskill and overlying Pocono formations (IX and X), instead of lying nearly flat, rise vertical from the underground, occupy on the map just the thickness which they possess geologically, and are cut through by the Lehigh, Little Schuylkill, Schuylkill, Swatara, and Susquehanna rivers at narrow, short, high, rocky water-gaps, showing the massive sandstone strata rising vertically from the water bed to the mountain crest, affording opportunities for a perfect measurement of each formation in each gap.†

This remarkable mountain outcrop of vertical rocks

† Of these the gap of the Schuylkill below Pottsville is thebest because the river makes a squarely transverse cut through the mountain. The Little Schuylkill is the most tortuous and unsatisfactory. The Lehigh river cuts square through the Pocono rocks, turns sideways along the middle softer measures, and then cuts squarely again through the Catskill. The Swatara gap is somewhat disturbed by the Schuylkill Haven anticlinal. The Susquehanna gap is clean and square, but the rocks are overturned to a 70° south dip.

many thousand feet thick, along an almost perfectly straight line fifty miles long, from Mauch Chunk to Pinegrove, presents one very notable feature. *Second mountain* is in fact double, having two separate crests of equal height (800′), parallel, and about 1000 feet apart, separated by a groove about 300 feet deep beneath the level of the crests. A cross section profile of the surface made almost anywhere takes on paper the shape of a cupids′ bow, or the upper lip of the human mouth. The internal constitution of the double mountain is thus revealed. The more massive hard grey sandstone beds of the Pocono (X) make the northern crest; the equally massive hard red beds of the Catskill (IX) make the southern crest; and an intermediate mass of thinbedded sandstones and hard sandy shales yielding more rapidly to the erosion of the rainfall makes the groove between the two crests.*

The Catskill terrace.

A twin mountain like this could only be made by twin formations, and only under the rare occasion of verticality in the dip. When the dip falls off from the vertical to 50° and 40°, the shape of such a twin mountain immediately changes to a mountain with one single and higher crest and a terrace. We have seen this in the case of mountains of IV, Medina-Oneida, such as Tussey, Stone, Dunnings, Canoe, etc., in the upper Juniata region. We see the same thing happening in the case of mountains of IX-X, Catskill-Pocono, like Peters' mountain, and indeed along all the outcrop above described,—the Pocono making the high single crest and slope flank, the Catskill, a boldly projecting terrace and lower slope on the underhanging side.†

* The reader may refer to the description in Vol. 1, p. 695, of the two equal crests and intermediate groove of the Bald Eagle mountain constructed in the same way; the Upper Medina (IVc) playing the rôle of the Pocono (X); the Oneida (IVa) that of the Catskill (IX); and the soft red Lower Medina (IVb) between them, that of the softer intermediate mass at Mauch Chunk. —See also the contour map of the Bald Eagle gap at Bellefonte on page 626.

† The finest view of this topographical feature is to be got from the Pennsylvania railroad after passing Duncannon and approaching the mouth of the Juniata. The Susquehanna, sweeping around Duncan's island, cuts deeply into the end of Peters' mountain on the eastern bank, shearing it

The Allegheny escarpment.

When the dip falls to 20° and 10°, and the Catskill formation is reduced in total thickness, a still further modification of mountain form takes place; the Pocono and still higher formations now make the main upper mass, from which project long fingers or spurs of Chemung capped with knobs of Catskill, between which large streams descend through picturesque gorges from the plateau above.*

The Catskill in Western Pennsylvania.

The difference between northern and western Pennsylvania is this: back from the Catskill outcrop to the north the Catskill continually rises slowly toward New York and cannot be kept from appearing frequently at short intervals at the surface; whereas it sinks to a considerable depth westward and underlies the bituminous coal region, appearing at the surface in the gaps of Laurel Hill and Chestnut Ridge, being cut through on the anticlinals by the Conemaugh at Johnstown and Blairsville, by the Loyalhanna, and by the Youghiogheny at Ursina and Connellsville. In all

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off diagonally, and exposing the south dipping red Catskill rocks of the terrace; from the terrace rises the steep upper slope of the intermediate mass, capped with the grey ribs of the Pocono crest; from this a long slope of upper Pocono strata descends southward. On reaching the Aquaduct the traveler gets a long vista of the *red terrace* receding far away eastward, with short ravines cutting down through it at regular intervals. But these ravines are not *double headed* as in the case of the terrace of IV surrounding Kishicoquillis valley. This is a plain indication to the geologist that the middle IX–X mass is nothing like as soft and easily eroded as the Lower Medina IV b. And if he will examine them where they descend to the river water level he will find this to be the case.

*Such is the constitution of the front escarpment of the Allegheny mountain its whole length of a hundred miles from Lycoming to Bedford county. The best place to study it is along the steep grade of the Pennsylvania railroad ascending from Altoona, Blair county, to the Tunnel summit, Cambria county. Looking down from the tunnel (900' above Altoona) the traveler sees the back or western sides of several of these outstanding knobs of Catskill rock. But from some standpoint on the high crest of the Bald Eagle or Brushy mountain, a spectator looking westward across the Tuckahoe (Altoona) Valley has before him an interminable row of these spurs and knobs, ranging away as far as the eye can reach to the northeast and southwest, and he can see their lower necks of connection with the main mountain, its upper slope, cut by ravines, and the higher crest surmounted by its own ranges of Conglomerate knobs.

western Pennsylvania it never comes to the surface (except in these gaps) until it appears as a very thin formation connected with the Venango Oil sands in Erie and Crawford counties and in Ohio. It is however passed through in all the oil wells at various depths according to their situations.

The Catskill around Broad Top.

The whole of this great formation has been swept away from middle Pennsylvania west of the Susquehanna river, except in Perry county, and in the deep synclinal trough of Huntingdon, Bedford and Fulton. It has been said that in Perry county it forms the outside terrace flank of the Cove and the Buffalo mountains. It remains to be said that it forms the terrace of Terrace mountain and Sideling hill around the Broad Top coal basin in Huntingdon, Bedford and Fulton counties.

Imagine an oblong saucer of Catskill, holding Pocono, Mauch Chunk, Pottsville and Coal Measures; one end of it projected northward across the Juniata for a few miles; the other end extending southward into Virginia. The mountain crest is Pocono; but the terraced outside flank all round is Catskill. Its typical section at Saxton will be given further on. Inside lie Trough creek and Woodchuck Valleys, surrounding, like the fosse of a mediæval castle, Broad Top mountain with its coal measures. No more flagrant proof of the fact that the Catskill formation in past ages overspread all middle and southern Pennsylvania could be presented for acceptance.

Another residuum from the general destruction of the formation is that oval outcrop of Catskill in Fulton county which surrounds Scrub Ridge, and Licking creek and Meadow Ground mountains in Fulton and continues southward in two synclinal belts into Maryland. (See the colored map of Fulton county in T2.)

Catskill outliers in Schuylkill, Carbon and Monroe.

Two other synclinal outliers of the lower beds of the Catskill formation may be noticed on the Geological map of the State. One caps the range of the Chemung hills south of

Schuylkill Haven, from Auburn half way to Pinegrove. The other caps the Chemung range of hills in Carbon county, from the Lehigh river southwest to the Schuylkill county line, and northeast into Monroe county. These outlying strips have been preserved along the center lines of two troughs with very gentle dips both north and south; and they consist of the soft lowest beds which may be considered transition red beds from Chemung to Catskill. If the Catskill formation had massive hard sandstone strata in its lower part as it has in its upper part then these ridges of Chemung would have resisted erosion and stood up as very respectable little mountain ranges.

Little Mountain.

It will be seen by an examination of the long Lehigh section to be given directly that some of the middle beds of the Catskill are hard enough to make a ridge; that the beds above them are softer; and that the hard and massive beds are in the upper subdivision of the great formation. The consequence of this arrangement of the strata is a topographical feature of the surface attracting the eye of the traveler, as well as the attention of the geologist. From the Lehigh to the Swatara there runs a *Little Mountain*, so called, in front of the high *Second Mountain* of the Catskill-Pocono vertical rocks already described, and separated from it by shallow side vales; this Little mountain occasionally becomeing a broad terrace to the Second mountain. The Little mountain is a narrow outcrop of the hard beds of the Chemung-Catskill group, standing vertical like the beds of Catskill-Pocono in Second mountain.

Chapter CVII.

IX Catskill in the the north-eastern counties.

To comprehend Prof. White's classification of IX, the Pocono (X) and Upper Chemung (VIII g) must be placed in consecutive order with it, as in the following general section in the north-east corner of the state: *

X. Pocono sandstone, buffish, pebbly,	40′
" Shales, buff, sandy and concealed,	200′
" Sandstone, buffish white, massive,	125′
" Shales with sandstones, gray, current bedded,	265′
" *Griswold Gap Conglomerate*, white,	35–665′
" *Rix's Gap fish bed* at its base,	
IX–X. Catskill-Pocono transition beds; concealed,	50′
" Sandstone, gray, current bedded,	15
" Concealed strata,	25′
" Sandstone grayish white,	20′
" Concealed strata,	25′
" Sandstone gray, current bedded,	15′
" Sandstone gray, and reddish shales,	200′
" *Mount Pleasant Conglomerate*	25–375
" *Mount Pleasant fish bed* at its base,	
IX. Catskill strata, proper; viz:—	
" *Mount Pleasant red shale*,	150′
" *Elk mountain* shales and sandstones,	150′
" *Cherry ridge conglomerate*,	20
" " gray shales,	20′
" " sandstone,	15′
" " *limestone*,	5′
" " *red shale*,	110′
" *Honesdale sandstone*, white,	25′
" " " *red*,	40′
" " " gray,	25′
" *Montrose red shale*,	180′
" *Paupack sandstone*,	25′
" " shales, *red* and green, and sands,	200′
" *New Milford upper* sandstone,	40′
" " " middle sandstone,	300
" " " lower sandstone,	25′
" *New Milford shales*, *red* and olive,	100′
" *Starucca shale*, gray and olive, with thin sand,	105–1530′

*G5, 1881, p. 56; in the Scranton and Carbondale region for the Pocono; in the surrounding counties for the Catskill. The Pocono rocks will be discussed in Chapter CXI in the beginning of Vol. III.

VIII.	CHEMUNG olive shales, with fossils,	20′
"	Sandstone (*conglomerate* in middle, 2′)	8′
"	Shale, olive, 8′; sandstone, olive, 4′	12′
"	*Mansfield shale* (*iron ore* near middle),	40′
"	" Shale, brick red,	10
"	" Sandstone, olive, green,	5′
"	" Shale, upper green, lower purple,	20′
"	" Shale (*Spirifer bed,? fish*),	15′
"	*Cascade* (*Fall creek*) *conglomerate*,	25′
"	Shale and sandstone, very fossiliferous,	30
"	Sandstone, brownish, prismatic,	25
"	Shale, bluish olive,	25
"	Sandstone, brownish, very fossiliferous,	15′
"	Shales, olive and flaggy, quite fossiliferous,	25
	to water in Cascade creek,*	275

Red color; current bedding; breccias.

The only notable difference between the so-called Catskill and so-called Catskill-Pocono groups of this section consists in a greater percentage of *red beds*, but even this does not amount to more than 40 per cent.; and when traced geographically the thinner red beds change to gray, and only the thicker and more massive ones keep their red color.—The sandstone beds, varying in thickness from 2 to 10 feet, are characteristically false bedded, or obliquely bedded, showing the action of strong currents of water. This feature is peculiarly developed in the Pocono formation

*The local names given by Prof. White to individual strata, or groups of strata, are good and useful; and he has carried them southward very successfully to identify the deposits in Pike, Monroe and Carbon counties on the Delaware and Lehigh rivers. But the general names of Pocono, Catskill and Chemung are of much less value, as it is impossible for geologists to agree on plain distinctions between them; that is, on fixed horizons which can be called their top and bottom limits. Neither fossil shell beds, nor fish beds, nor red shale beds serve to fix such limits in this northern region where the whole thickness of deposits is so much thinner than it is fifty miles further south. In the whole mass of 2740′ measured by Prof. White there is no break in the deposits from the base of the great Conglomerate (XII) down into the Chemung (VIII g). On the Lehigh, where the same pile of XI, X, IX is more than 10,000 thick, this difficulty is diminished, because XI makes a deep valley, and X and IX together a high double crested mountain, a vale and another lower mountain. It was here that the First Geological Survey of the State fixed the limit between Pocono (X) and Catskill (IX) by the two crests of the Mauch Chunk (or Second) mountain; leaving however the limit indefinitely drawn somewhere along the middle of the groove between the crests. Prof. White however thought, when his surveys reached the Lehigh, that the Pocono or northern crest ought to be made the top of the Catskill.

of the Allegheny mountain outcrop its whole length, but especially in Cambria and Somerset counties on the Maryland line; so that "current bedding" affords no good distinction between Catskill and Pocono. This oblique lamination marks the cliffs very curiously with zigzag furrows produced by the weather acting on the edges of oblique layers, 2 or 3 inches thick, sloping one way above and the other way below, as if the water currents were constantly changing their direction.* But when the sandstone beds are quarried they are found to consist of regular horizontal layers of sand from 1 to 3 inches thick, which have nothing to do with the zigzag layers of the current bedding.

Calcareous breccias are very common in this region of the Catskill, less frequently in the Pocono; always constituting the base of a sandstone mass; made up of dark olive hard slate fragments cemented by limestone; and sometimes thickening to 5 or even 8 feet, and assuming the appearance of an impure limestone bed; frequently containing pebbles of sandstone, and sometimes of quartz, and often what seem to be broken up *fish bones*. Even the limestone matrix looks as if it had been swept in from some older limestone mother rock.

Coal streaks, half an inch or an inch thick, are sometimes seen; but of course no workable bed or anything approaching to one has ever been found, although a great deal of digging has been done here and there in the country.

No bed of *iron ore* has ever been found; but *manganese black oxide* (wad) is scattered about in very small worthless quantities.

Copper glance and *nickle* are occasionally seen in the red shale near Honesdale, but amount to nothing.

Plant fragments are sometimes seen; badly preserved leaves and stems, which had floated far before deposite.

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*See a picture of it in Vanuxem's report on the 3d or Middle district of New York, 1844, page 187, Fig. 53. In most cases the oblique leaves of sand fine out downward and curve forward to coincide with the bed planes. Their tops however are planed off as if the next current of water had removed their upper parts. In other words, we have a plain exposition of the way all sand banks are made; the sand deposited by a current setting in one direction to-day being partly carried away by a different current which deposits the next layer or bed of sand to-morrow.

Among them Prof. Dolph recognized in the Paupack sandstone near Honesdale a specimen of *Archæopteris jacksoni.* But Prof. White never found a single fossil shell in his whole survey. In other parts of the State the Catskill formation is equally destitute of remains of animal life.

The Mount Pleasant red shale is a well marked widespread deposit, well exposed along the road descending from that village; and also under Prospect Rock in the South Knob.

The *Elk Mountain gray shale* covers wide areas but is seldom well exposed to view. In some places it holds a good many current bedded layers of sand.

The *Cherry Ridge conglomerate*, of coarse and fine sand, hard and whitish gray, full of quartz pebbles in southern Wayne, caps Collins' high knob just west of Cherry Ridge P O. It has been swept from off Susquehanna county except along its eastern edge, where the *calcareous breccia* at its base (in Wayne) turns to a *black* stratum, 5′ thick. Shales, 25′ thick, separate it from the 15′ gray sandstone, current bedded, which makes a conspicuous rock ledge at hundreds of places in all parts of Wayne; but approaching Pike it grows coarser and holds plenty of reddish white quartz pebbles. Its crevices are studded with rock crystals some of them an inch long. Under it everywhere lies the *Cherry Ridge limestone*, outspread over a large part of Wayne county and the eastern edge of Susquehanna. It is in fact the lower portion of the sandstone, with no plane of division from it, and very irregular in thickness. It differs in its outspread from the numerous *calcareous breccias*, for these are all quite local. It is however no true limestone formation, as analyses of four specimens by Mr. McCreath prove, viz: *

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* Mr. Schenk turns out a fairly good land lime, which is said to excel barnyard manure. Loose boulders are so numerous on the surface of Wayne county, that considerable quantities might be collected for burning. They weather dark, and are known as Nigger Heads; from 2 to 10 feet in diameter. The cutting through this rock on the Jefferson Branch railroad tested the excessive hardness and toughness of the rock; its black outcrop being traceable from Gadjaw pond 1 mile S. of Honesdale, northward along the Lackawaxen and over the high land nearly to N. Y. State line; also from Cherry

Siliceous matter,	28.80	65.47	75.22	80.95
Carbonate of lime,	64.40	19.80	17.70	11.20
Carbonate of magnesia,	1.82	3.52	1.59	1.66
Ox. iron and alumina,	1.15	8.90	4.43	5.00
Phosphorus,	0.05	0.09	0.03	0.04

The Cherry Ridge red shale is a thick and persistent formation throughout the region, often subdivided by a middle group of gray current bedded sandstone beds.

The *Honesdale triple sandstone* mass is also a thick persistent formation, well exposed around Honesdale in Wayne and making the high ground near the Fair grounds at Montrose in Susquehanna.* *Its upper division* is so much *whiter* than anything in the country that its outcrop can be seen from afar. But the whiteness is confined to the weathered surface; inside, it is dark, or grayish brown, made so by specks of iron oxide. It makes the long cliffs a mile south of Honesdale, and many others elsewhere. *Its middle division is the only red sandstone in the whole Catskill of Wayne county;* all other red rocks being red shale. It is however light red, and made so by the greater multitude of specks of iron rust. It is quite hard, finegrained, usually thinly laminated, with a good deal of clay in it. It caps the *Irvine cliff* † opposite Honesdale; and its boulders are mixed in with the Ice Drift. *Its lower division* is made up of massive, gray, current bedded sand rock strata, forming the two miles of cliffs along Dyeberry creek above Honesdale. It has no pebbles in it in the region to the north; but towards Pike county it becomes a regular conglomerate; as on the hill tops east of White's mills. It can be traced into Scott township near the N. Y. line. It caps some hills also in the middle of Susquehanna county.

Ridge southward into Pike county; also, as a black ledge 8′ to 10′ thick, around Elk mountain, at 600′ to 700′ below the crest, along the highlands nearly to Starucca. It is the *Catskill limestone* of the New York geological survey (1835–1844); and its various exposures and local characters may be found in Prof. White's detailed description of the townships of Susquehanna and Wayne in G5, 1881.

* Vanuxem called it the *Montrose sandstone*, a term often used in White's township reports. But the term *Onconta sandstone* is wholly wrong; for that name belongs, as Prof. Hall has fully proved (1892), to the *Portage* in eastern New York, underlying the Chemung.

† 300 feet high and nearly vertical from the bank of the Lackawaxen up.

The *Montrose red shale*, exposed in the streets of that borough, is especially well shown on the road down to the Wyalusing, and reddens the surrounding hill country ; two thirds of its mass being solid red shale, the rest of it interbedded gray sands. It makes a great red show also under the Honesdale cliff.*

The *Paupack quarry sandstone* is a beautiful bluish-green serpentine-like rock, confined to southern Wayne; overlying 200′ of greenish gray current bedded sandstone beds, separated by green, olive and sometimes red shales.†

The *New Milford upper sandstone*, massive, greyish, current bedded, makes long lines of cliffs near the hill tops of northern and central Susquehanna county ; finely seen along Marten's creek ; in the hill top railroad cut from Summersville to Great Bend ; and in Hickerman Ledge north of Great Bend.—The *middle sandstone and shale*, in regular alternations (some red), crops out on side slopes over a great extent of northern Susquehanna.—The *lower sandstone* (*the lowest Catskill current bedded sandstone*) makes a great show in the hill opposite to and 70′ above the New Milford RR. depot (1150′ A. T.); in continuous cliffs all the way to "Fort 76 Cliff" overhanging the Great Bend of the Susquehanna, 400′ above the river bed ; and so on in frequent cliffs along the right bank past Susquehanna Depot ; a grand geological guide to the top of the Chemung formation 200′ underneath it (according to

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*The copper and nickle shales of the old reports of the First Survey lie at the very top of this great mass of red shale.

†The Honesdale churches, and the silk factory at the mouth of Paupack are built of it. Prof. White found no rock similar to it anywhere in his district.—The quarries are described in his Report G5, p. 187. In those above the creek road along the buff there is an intermittent irregular calc. breccia near the top of the quarry rock, which holds many fossil plants. A fine section by the Walleupaupack cascade just below Hawley (p. 199). There is first a fall of 20′; then follow rapids; then three successive cascades, with short rapids between, the stream descending 145′ vertically in 300′ of its course. It is the finest water power in the country ; yet used only for a tannery and flour mill. A silk factory was built in 1881 to take from the first cascade, 50′ above its turbine. The sandstone is extensively quarried along the banks ¼ m. above the upper cascade ; in layers 4 to 8 inches thick (1050′ A. T.). It is a beautiful building stone, looking like Delaware county serpentine (p. 200).

Prof. White's arrangement). It rises along the Erie RR. to the Summit cut, 1525 A. T. Followed to Deposit it is there only 100′ above the river and goes under at the State line.—In the S. W corner of the county there are in it *flagstone quarries*, with a face of 20′.—At the quarry on Tuscarora creek, 1¼ m. W. of Skinner's Eddy, 240′ above the river bed, it holds many *plant fragments* (G5, p. 70).

The *New Milford deep red shale* shows finely along the D. L. & W. RR. half-way to Montrose depot, with occasional sands holding irregular calc. breccias. In Wayne it is everywhere under ground.

The *Starucca olive* shales, with many thin sands, and one more massive sometimes at its top, is perfectly exposed in the Erie RR. Summit cut on the divide between the Delaware and Susquehanna rivers. This Prof. White makes the base of the Catskill No. IX.

Dutch Mountain section and Mehoopany No. 1 Well record, in Wyoming Co, (G7, p. 141, and fig. 45, p. 138, reduced on plate CLXXXX, below).

The surface rocks of North Branch township, Wyoming Co. are largely Catskill. Dutch mountain is capped with horizontal Pocono strata. The Mehoopany Oil Co.'s boring on the bank of the creek, 1½ m. N. W. of Lovelton, at the foot of the mountain, which is 900′ high, begins at 1350′ A. T. and is 2089′ deep, descending to 739′ below sea level. Mr. Judson Stark of Tunkhannock kept one hundred samples from 800′ down to the bottom. Cascades of a brook near by furnish a good air section above the well, which will be given in the chapter on Pocono X, in the Third volume of this Final Report.

Wyoming Co. Section by I. C. White.

X.	*Griswold Gap conglomerate, visible,*	30′
X–IX.	Transition strata, massive, gray, current bedded sandstone, weathering yellowish, some slightly pebbly (with only 10′ of red in the whole),	370
IX.	*Red shale,*	25
"	Sandstone, flaggy, greenish,	55
"	*Red shale,*	35
"	Sandstone, greenish (cascade),	25

"	Concealed interval,	10	
"	Sandstone greenish,	20	
"	Concealed,	35	
"	Sandstone, greenish (cascade),	20	
"	*Red shale*,	10	
"	Sandstone, green (cascade),	15	
"	*Red shale*,	10	
"	Sandstone, green (cascade),	20	
"	*Red shale*,	30	
"	Sandstone, green, massive (cascade),	30	
"	*Red shale*,	10	
"	Sandstone, greenish (cascade),	20	
"	*Red shale*,	30	
"	Sandstone, grayish (cascade),	40	
"	*Red shale*,	5	
"	WELL MOUTH; conductor in Drift,	38	
"	No record of sandstones and *red shale* beds kept for	754	
"	Sandstone, whitish (some gas),	8	
"	*Red* rocks, not specified,	200	
"	Sandstones and *red* rocks,	175	1620
IX-VIII.	Sandstone, whitish,	25	
"	(unrecorded),	75	
"	Sandstone, hard, reddish,	25	
"	*Red shale*,	20	
"	Sandstone, grey, hard,	30	
"	Sandstone, whitish, small quartz pebbles,	30	
"	Shales, bluish green,	50	
"	Sandstone, gray,	3	
"	(unrecorded),	52	
"	*Red* rocks ("Big Red" of driller).	40	
"	Sandstone, hard, bluish green,	25	
"	(unrecorded),	10	
"	*Red* rocks ("Little Red" of driller),	25	
"	Sandstone, hard, blue, micaceous,	5	
"	Grayish green rock (smell of gas),	20	
"	*Red shale and sandstones* ("oil show"),	7	
"	Sandstone, greenish gray,	15	
"	Red shales, sandy,	31	
"	Sandy beds, hard, gray,	58	
"	Red shale, sandy,	12	
"	Sandy bed, hard, gray,	20	
"	Shale sandy, hard, blue and blackish,	80	
"	*Purple shales*, sandy,	52	710
VIII.	Sandstone, greenish, gray,	10	
"	Sandstone, *pebbly*, whitish ("some oil"),	9	
"	Sandstone, gray,	5	
"	Shales, sandy, dark,	5	
"	Sandstone, light gray,	5	
"	Shales, sandy, blue,	142	
"	Shales, greenish, mixed with purple which may have dropped from above,	28	

The subdivisions, and their assignment to X, Pocono; X–IX, Pocono-Catskill; IX, Catskill; IX–VIII, Catskill-Chemung; and VIII. Chemung are the best that Prof, White could suggest. No fossils were seen; no oil obtained. The thickness of 1620′ to the Catskill subdivision is curiously near the 1530′ of White's general section given above.

Tioga river section (*G5, 72*).

Prof. White made the following section along the Tioga river in Tioga county which will suffice to illustrate by comparison with his general section given above the thinning of the deposits westward. His Delaware river section to be given next will show their thickening southeastward; and his sections in Pike, Monroe and Carbon their much more considerable thickening southward.

XII.	*Pottsville conglomerate* (bottom mass),		60
XI.	*Mauch Chunk red shale* (interval),		245
X.	*Pocono Sandstone*, massive,	20	
	Concealed (dip 6° to 8°, 1 mile) say,	500	
"	Gray sandstone,	25	
"	*Calcarous breccia*,	3	
"	Gray sandstone,	25	573
IX.	*Catskill red shale*,*	35	
"	Sand, greenish, current bedded,	15	
"	Shales,	5	
"	Sand, thin beds, current bedded,	40	
"	Shales? in interval of	250	
"	Sands, finely laminated, greenish,	30	
	Concealed interval,	50	
"	Sand, current bedded, greenish,	20	
	Concealed interval,	350	
"	Red shale and sandstone,	35	
"	*Fish conglomerate*,	2	
"	Red shale and sandstone, visible,	200	
	Concealed to top of VIII, possibly only	100	1122

Total in Tioga county, 1940′; in Wayne, 2740′; thinning westward, 800′; rate 10′ per mile; which if maintained all the way to Titusville on Oil creek, Venango county, 140 miles west of the Tioga river, would reduce the same column by 1400′ to 540′ which Prof. White in his Erie and Crawford Report, Q4, considers as a close approximation to his measurements there (G5, p. 73).

* Here Sherwood's report G puts the top of the Catskill.

CHAPTER CVIII.

IX. Catskill in Pike, Monroe and Carbon.

The formation, which is only 1530′ in Susquehanna, increases to 3430′ in eastern Pike, where Prof. White made the following section :—

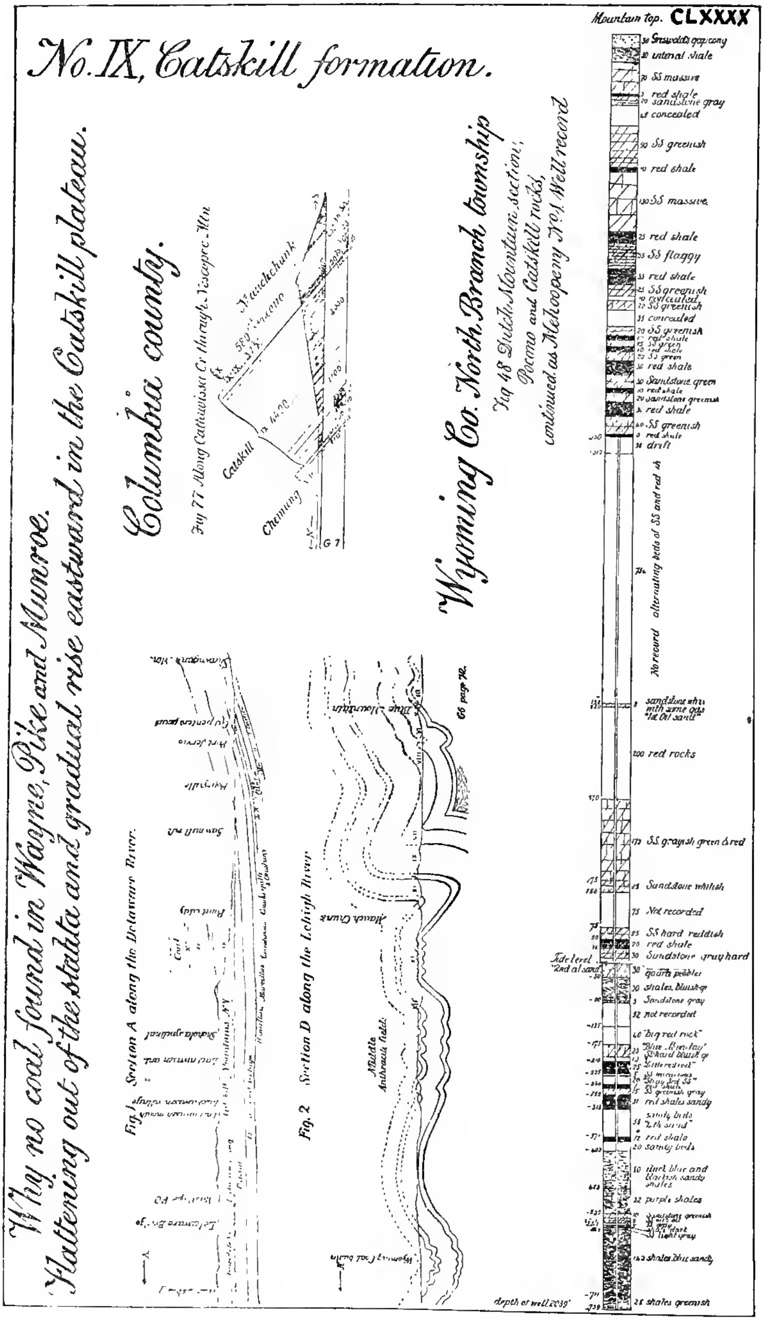
Delaware river Section (*G6, p. 73.*)

Honesdale sandstone group; two sets of massive pebbly strata, each 30′ thick, separated by 40′ of red sandy shale, ...	100
Montrose red sand, with a little shale at top, ...	125
Red shale, ...	100—225
Greenish grey sandstone beds, ...	30
Lackawaxen conglomerate, ...	50
Greenish current-bedded sandstone strata, each 20′ to 30′ thick, alternating with greenish grey shales, .	300
Red shale, ...	50
Delaware flags (New Milford sandstone group?) ; alternate bluish-green and greenish-gray standstone beds, 20′ to 40′ thick, separated by greenish sandy shales; only one reddish bed (10′ to 15′) in the whole interval. These *Blue Stone* quarry beds split into large smooth layers from 3 to 6 inches thick, ...	1000
New Milford red shale, ...	20
" " green sandstone, ...	40
" " red shale, ...	15— 75
Starucca sandstone group, greenish gray, to river bed ½ m. above E. RR. bridge, 4½ m. above Port Jervis, .	say 600

Here the *Chemung* top rocks begin to rise from the water, down stream. There are visible outcrops along the Delaware river of about 2430 feet of Catskill strata, i. e. from the base of the formation up to the *Honesdale sandstone* cliffs which cap the river hills.

IX at Honesdale in Wayne county.

But a much minuter description of more than 2000 feet of IX has been obtained by a boring made on Dyeberry creek 4 miles north of Honesdale, commencing about 200′ beneath the base of the *Honesdale sandstone group* (at about


No. IX, Catskill formation.
Mountain top. CLXXXX
Why no coal found in Wayne, Pike and Munroe.
Flattening out of the strata and gradual rise eastward in the Catskill plateau.
Columbia county.
Fig 77 Along Catawissa Cr through Nescopec Mtn
Mauchchunk
Catskill
Chemung
Wyoming Co. North Branch township
Fig 48 Dutch Mountain section;
Pocono and Catskill rocks,
continued as Mehoopeny No. 1 Well record
Fig. 1 Section A along the Delaware River.
Fig. 2 Section D along the Lehigh River
Middle Anthracite field.
Mauch Chunk
Blue Mountain
red shale
SS massive
SS greenish
SS flaggy
concealed
red rocks
No record alternating beds of SS and red sh
SS grayish green & red
Sandstone whitish
Not recorded
SS hard reddish
Sandstone gray hard
quartz pebbles
purple shales
shales blue sandy
shales greenish
depth of well 2039'

1050′ A. T.) and descending to a depth of 2165′ (1115′ below sea level), i. e. into the *Starucca sandstone group.**

This important well-boring was made by the Wayne Co. Oil Co. under the enlightened supervision of its President, Mr. Edward F. Torrey of Honesdale, who permitted its record to be published in Prof. White's Report, G6, 1882, p. 92, 93, and Appendix, p. 365 ; as follows :—

IX. Dyeberry creek well record, 2165 deep.

Conductor hole, through drift,	36′	to	36′
Red shales and gray sandstone,	29		65
Reddish sandstone,	10		75
Red sandy shale,	5		80
Sandstone, greenish-gray, with quartz pebbles,	5		85
Sandstone, reddish-gray,	15		100
Red sandy shale,	10		110
Sandstone, greenish-gray,	26		136
" " some pebbles,	4		140
" brownish-gray, fine,	3		143
" greenish-gray, coarse,	4		147
" gray, pebbly,	5		152
" greenish-gray,	8		160
" grayish-brown,	5		165
Shale, greenish, sandy,	8		173
Sandstone, gray, with reddish tinge,	5		178
" gray,	5		183
Shale, sandy, micaceous,	7		190
Sandstone, dark gray,	4		194
Shale, gray, quite sandy,	6		200
Shale, dark red,	15		215
Slate, bluish-green,	40		255
Sandstone, greenish-gray,	175		430
" shaly, brown,	30		460
" fine, greenish-gray,	20		480

*The well failed in its object, as I predicted. It would probably have found no oil had it gone down into the Chemung strata proper. It stopped in the middle of the *Starucca group* of sandstones, which is only 105 thick in northern Wayne, but 600′ thick along the Delaware river in Pike. As Honesdale is about half way between Great Bend and Port Jervis, this boring would have to go to 2500′ to strike the true Chemung rocks. As there are 800′ of Catskill strata above the mouth of the well, we get a total thickness of Catskill at Honesdale, say, 3200′. This is even greater than in the Delaware river section. Consequently the whole formation *thickens* from its Great Bend outcrop towards the well southward about 25 miles from 1530′ to 3200′ (1670′) i. e. at the rate of say *67′ per mile*, and then slightly southeastward to 3430′ on the Delaware river. Southwestward it reaches 4200′ in the Spragueville section, 5325′ on Broadhead creek, Monroe Co., and 7545′ on the Lehigh. (See White's table of thicknesses, G6, 94.)

Shale, greenish, sandy,	35	515
" gray, sandy,	15	530
Sandstone, greenish-gray, small pebbles,	30	560
Sandstone, dark gray,	5	565
Sandstone, dark red,	35	600
Shale light red,	10	610
Shale, dark, sandy,	20	630
Sandstone, greenish-gray,	10	640
Shale, red,	45	685
Sandstone, greenish-gray,	30	715
Shale, light gray, sandy,	5	720
Sandstone, dark gray, shaly,	20	740
" light gray,	20	760
" fine gray,	10	770
Shale, red (fresh water cased off at 778′),	30	800
Sandstone, reddish-gray,	25	825
Shale, dark red, sandy,	10	835
Shale, gray, sandy,	30	865
Sandstone, greenish-gray,	10	875
Shale red,	5	880
Sandstone, hard, greenish-gray,	20	900
" greenish-gray, micaceous,	30	930
Shale, bluish, sandy,	95	1025
Sandstone, gray,	50	1075
" greenish-gray, small pebbles,	25	1100
" greenish-gray, pebbly,	20	1120
" gray (weak vein of *salt water*,	20	1140
" shaly, gray,	10	1150
" greenish-gray,	15	1165
Shale, green, sandy,	25	1190
Sandstone, greenish-gray.	5	1195
" hard, gray,	10	1205
Sandstone, coarse, greenish-gray,	5	1210
" gray, small pebbles,	10	1220
Shale, red,	15	1235
Sandstone, coarse, (strong vein of *salt water*,	15	1250
Sandstone, greenish-gray, fine,	5	1255
Red shale, sandy,	10	1265
Sandstone, coarse, greenish-gray,	17	1282
" yellowish-brown,	13	1295
Shale, dark red, sandy,	30	1325
Sandstone, gray, small pebbles,	5	1330
" fine-grained,	10	1340
" greenish,	5	1345
" greenish-brown,	10	1355
Shale, dark-gray, sandy,	5	1360
Sandstone, shaly, micaceous,	35	1395
Shale, reddish, sandy,	5	1400
Shale red,	36	1436
Sandstone, shaly red,	5	1441
Shale, dark red, sandy,	5	1446
Shale, red, dark,	5	1451

Sandstone, grayish-green, micaceous,	10	1465
Shale red, sandy,	20	1485
Shale dark red,	20	1505
Red shale,	5	1510
Greenish-gray sandstone,	15	1525
Light gray fine-grained sandstone,	20	1545
Sandstone, greenish-gray,	10	1555
Shale, red,	5	1560
Sandstone, light,	15	1575
Sandstone, dark red,	35	1610
Sandstone, light gray,	25	1635
Shale, red, sandy,	35	1670
Sandstone, dark gray,	10	1680
Sandstone, light gray,	35	1715
Sandstone, greenish-gray,	15	1730
Shale, blue, sandy,	30	1760
Sandstone, greenish-gray,	60	1820
Shale, red, sandy,	5	1825
Sandstone, light gray,	10	1835
Shale, dark, sandy,	30	1865
Sandstone, dark gray,	20	1885
Sandstone, greenish-gray,	15	1900
Sandstone, very hard, gray,	25	1925
Shale, dark, sandy,	5	1930
Sandstone, greenish-gray,	20	1950
Sandstone, very hard, greenish-gray,	60	2010
Sandstone, yellowish, very silicious,	30	2050
Sandstone, dark gray,	10	2050
Sandstone, greenish-gray, very hard to bottom,	115	2165

Why no Coal basins east of the Lehigh.

It is easily seen from the above sections that the Anthracite Coal measures with the Pottsville conglomerate (XII) under them, the Mauch Chunk red shale (XI) under it, and most of the Pocono gray sandstone formation on which that rests, have all been swept away from the Pocono mountain plateau between the Lehigh and the Delaware, and of course from all the Catskill mountains of New York. That the Anthracite Coal measures once overspread the whole region of northeastern Pennsylvania and eastern New York is evident; and there can be little doubt that they extended to Rhode Island; and perhaps without break to Nova Scotia and Newfoundland; and even across the North Atlantic to England, Belgium and Prussia. The combined thickness of coal measures (3000′), Conglomerate (1500′), Mauch Chunk (2000′), and Pocono (2000′), thus swept from off the plateau would amount to 8000 or 9000 feet; giving an original height of at least 13,000′ above the sea at the Hudson.

On plate CLXXXX facing this chapter the reader will see two longitudinal sections placed over each other for comparison, the one along the Delaware, the other along the Lehigh. These show how the deeply folded anthracite basins flatten out and rise into the air eastward, carrying the coal many thousand feet into the air before reaching the border of New York state. The geological state map shows how the anthracite basins point out eastward and upward into the air. All search for workable coal beds east of the Lehigh has long since ceased, in spite of occasional discoverings of slight irregular coal seams of no importance in the Pocono formation on the headwaters of the Lehigh, on the Pocono plateau. The very rare occurrence of such seams in the Catskill formation of the northeast counties and elsewhere in the State are of no value except to seduce people to waste money in opening their delusive outcrops.

Blue Stone quarries on the Delaware.

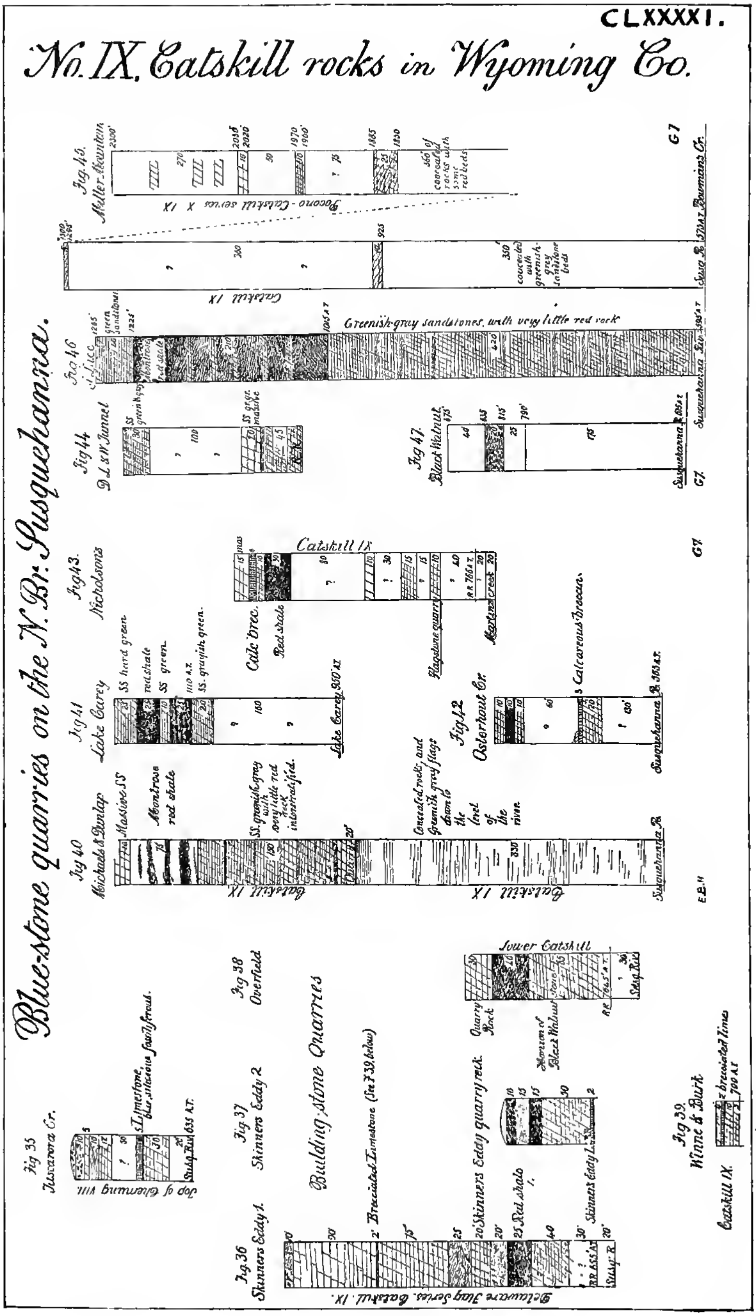
At Pond Eddy, near the S. E. corner of Shohola township, Pike county, the Erie railroad track is 60′ above the Delaware river; at the base of a sandy *red shale* formation 25′ thick; over which are cliffs of gray-green flagstone strata for 250′; then unknown layers for 25′; over which flag stones, 80′, in which are the principal quarries; but quarries have been opened in good beds at all elevations above the *red shale.* Beers & Co. and Kilgore are the principal operators. The flags are greenish-gray, quite smooth, and of very even thickness; but the division planes have something to do with the action of the weather, for they disappear as the quarries are worked back into the hill; so that they are always situated along the prominent cliff outcrops where the rocks have been most exposed. The stone is somewhat micaceous; the smaller crevices are filled with uncrystallized quartz; those an inch or so wide have their sides set with long slender *rock-crystals.* Large exportations to New York and other cities are made for pavements, side walks, etc. The great Vanderbilt mansion pavement slab, 6 inches thick, measures 10′ by 15′ (G6, 190).*

Blue Stone quarries in Wyoming Co.

In Braintrim township the largest quarry is on Tuscarora creek just above Skinner's Eddy ; Fordyce, Kempler & Co. shipping large quantities of stone to New York and other markets for lintels, door steps, etc. The quarry beds are fine-grained layers, from 4 to 12 inches thick, at the out crop, uniting in the hill.†

*Near Kimball's in Lackawaxen township are many quarries, which ship by railroad and canal, at all elevations from the bed of the Lackawaxen up to the hill summits 450′ above the water. Flags of two to five inches can be got of any desirable size (G6, 160).—Lebrau's quarry is on Last Hope creek, just above Pine Grove (p. 163).—A great many quarries have been opened along Blooming Grove creek, shipping flags at the Millville station ; the most extensive of which are on the hillside half a mile above the village. Here the section is:—Cliffs of sandstone, 20′; concealed, 40′; sandstone, 30′; concealed, 20′; sandstone, 20′; *quarry flags*, 20′; sandstone, 10′; *quarry flags*, 25′; concealed, 50′; massive pebbly sandstone, 25′; concealed to creek (785 A. T.) 45′; total hillside, 305′; the quarries are worked by Joy & Adams ; flags 1½ to 5 inches thick at the crop. Some of the layers contain *quartz pebbles, slate chips, fish bones* and *plant stems,* 1½ to 2 inches in diameter, pressed flat into a coaly film, and crossed by thin septa of a bony aspect which at first glance suggests animal remains. (G6, p, 165).—In Palmyra township, along Kimball's run, Kimball's quarries furnish excellent stone, bluish green, quite micaceous, occasionally containing chips of dark olive slate which often has a *stickensided* appearance. (G6, p. 170).—The Shohola bridge section, No. 7, 80′ thick, 418′ above the Delaware river, has been largely quarried by Chauncy Thomas. Other quarries open strata down to the Lackawaxen conglomerate (25′) the top of which is 158′ above water (G6, p. 187). In Westfall township between Pond Eddy, and Sawmill rift, at Stairway, Killgore & Co. have several large quarries of large and beautiful flags (p. 194).—In Milford township, Stichler's quarries is in Catskill cliffs, dipping 15°, N. 15° W. (p. 199).—In Monroe county, Paradise township, the Delaware flagstone beds are well exposed along West Broadhead's creek and extensively quarried by Doyle, Norton and others; greenish-gray, splitting into very smooth flags of almost any size (G6, p. 319).—In Barrett township J. H. Price's extensive quarry is ¾ mile east of Oakland station ; dip 13°, N. 25° W.; 1150 A. T.; excellent stone shipped to Scranton and further north (G5, p. 325).—In Price township a quarry has been opened on Broadhead's creek (p. 322).

† The section here is : Gray sandstone, 5′; shales, sandy, olive, 10′; *Quarry course of bluish-gray sandstone*, 12′; interval concealed, 30′; *Fossiliferous limestone*, blue, hard, siliceous, 5″, flaggy and shaly bluish sandstone beds,


CLXXXXI.
No. IX. Catskill rocks in Wyoming Co.
Blue-stone quarries on the N. Br. Susquehanna.
Building Stone Quarries

The Wyoming Stone Company in Meshoppen township, next east of Braintrim, and between the Susquehanna river and the Susquehanna county southern line, has a large quarry ½ m. N. of Black Walnut Station on the Lehigh Valley RR. and 90′ above RR. grade (649′ A. T.). The fine-grained bluish-gray rock with a tinge of green, is 50′ thick. From its various courses are taken building stones, steps, sills, and flags of all sorts.*

Overfield's large quarry is 2 miles below Black Walnut, in a stratum, 30′ thick, 125′ above RR. grade, and about 100′ higher in the series than the Black Walnut quarry strata; it furnishes fine large flags and heavier building stone.†

Brownscomb & King's great quarries are on Little Meshoppen creek, ¼ m. N. of Meshoppen village, 80′ above RR. grade, in rather massive bluish-gray fine-grained sandstone, 45′ thick, in courses of 6″ to 4′, separated by thin bluish shales. The best stone is the bottom course, which is sawed and *polished* into ornamental work at the company's mills at Meshoppen.‡

Winne & Burk's quarry, a few rods south of the last, and at a lower level, takes some flags from a 10′ stratum

30′; down to Susquehanna river (635′ A. T.), 20′. *The limestone*, a solid mass of coarse and distorted shells (somewhat like *Spirifer disjuncta*), is probably the same as that which occurs near the top of the Chemung rocks at so many places in Tioga, Bradford and Susquehanna counties; and is perhaps the same as Claypole's *Newport limestone* in Perry county to be described in the next chapter. Sinking south, down river, at the rate of half a degree (50′ or 75′ per mile), into the bed of the river about five hundred yards below Skinner's Eddy, where it is full of spirifer shells and *plant* fragments. Here is a quarry of bluish-green flagstone beds, 3″ to 5″ thick, of very fair quality. Near this the cliffs rise vertically from the river bed to a height of 360′ (see Skinners Eddy section, G7, 117, fig. 36). The beds represent the lower portion of the *Delaware flagstone series*.

*In the body of this mass, 10′ above its base, occurs one of those curious *brecciated limestones* made up of *fish remains* and *plant fragments* (G7, 118).

† Under it lies a *red shale* formation, 40′ thick holding macerated flattened stems of *Archæopteris hybernica*.

‡ Here also, 25′ above the base, runs a course of *brecciated limestone* irregularly between the flagstone courses, fine specimens of *A. hybernica*, and another (probably new) species of *Archæopteris*, may be collected from the shale partings in the quarry. Many stems and broken fragments are scattered through the coarser portions of the sandstone layers (G4, 119).

under a brecciated limestone layer (2′ thick), but its building stones from a 5′ stratum next below (G7, 120).*

The Newport limestone in Perry Co.

This limestone, at the base of the Catskill, or top of the Chemung in Perry county, is hardly identifiable with the *Skinner's Eddy limestone*, described in a foot note on page 1593 above, as spreading widely through Wyoming, Bradford, Tioga, and Susquehanna counties in the northeastern corner of the state; for it is described in Claypole's Report F2, p. 224, as a *local* deposit (3′ thick) best exposed opposite the furnace at Newport, and 1 m. E. on the bank of the Juniata as a lenticular mass of fossil shell-casts and siliceous matter.†

IX, Catskill on the Lehigh river.

In the gap of the Mauch Chunk (or Second) mountain two railroads and a canal have cut bold and continuous exposures of the Pocono, Catskill and Chemung formations, the strata of which rise vertically from the river bed to the top of the double-crested mountain. Of these strata both Prof. White and Mr. Winslow (of the Anthracite survey) have made separate and independent sections.‡

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*Since White's survey of Wyoming in 1882, many quarries have been opened northeastward along the line of railroad and creek.

† Three analyses by McCreath give:—Carb. lime 60, 49, 33; Carb. mag. 2, 2, 2; ox. iron and alum. 5, 6, 8; phos. 0.07, 0.08; siliceous matter 32, 42, 54. These analyses show that it is a sandy shale with varying quantities of decomposed shell matter. It is the chief water-bearing stratum for the southern part of the town of Newport, furnishing very hard water. It was once assumed as the base of the Chemung; but in fact it lies high up in that formation, and may be assumed as the base of the Catskill-Chemung Transition series. It is only seen in Howe and Oliver townships of Perry county. It is crowded with Chemung species, especially *Strophodonta demissa.*

‡ They differ a good deal in their measurements and descriptions of the individual beds, but considerably more in their measurements of the formations as a whole. Prof. White was guided in his general grouping by the system of subdivisions which he first adopted in Susquehanna and Wayne counties, and brought forward in his surveys of Pike, Monroe and eastern Carbon to the Lehigh river. Mr. Winslow had previously established no such subdivisions, and saw nothing but the general Pocono mass of grey sandstones, the general Catskill mass of red sandstones, and the general Chemung mass of olive shales and sandstones extending down the river to the overturn anticlinal near Lehighton.

Winslow's Section No. 13; from Mt. Pisgah over Mauch Chunk, down the Lehigh river, to Lock No. 7 at Lehighton.

XII.	POTTSVILLE CONGLOMERATE,		1000′
XI.	MAUCH CHUNK RED SHALE,		2168′
X.	POCONO SANDSTONE, beginning 1000′ S. of the East Mauch Chunk RR. station.		
"	SS., hard, gray; with cong. beds (White's No. 1),	440	
"	Shale and slate, dark,	20	
"	SS., coarse grained, grayish,	26	
"	Slate, dark,	13	
"	Pebbly SS. dark gray, (White's No. 2),	50	
"	Conglomerate, coarse, (White's No. 2),	14	
"	Shale and SS, greyish-green,	28	
"	Yellow ochre,	5	
"	Shale, greenish,	13	
"	Yellow ochre,	5	
"	Shales, olive green, ochrey,	55	
"	SS. dark gray, with shale and slate,	282	
"	SS. white, fine "soapstone" bed at base,	48	
"	Shales, dark, greenish and variegated,	40	
"	SS. dark-gray and reddish, with a few large scattered pebbles (passing the Mauch Chunk RR. station),	214	1253
IX.	CATSKILL (White's Mt. Pleasant conglomerate was sought for but not found by Winslow).		
"	SS. red, with glassy quartz grains,	32	
"	Shales, ochery,	9	
"	SS. grayish, green,	27	
"	Shales, red,	18	
"	SS. shaly, light green, fine,	5	
"	Shale, red,	9	
"	SS. red, hard (at RR. Station about 100′ S. of 106th mile stone),	72	
	The next 800′ make the crown and crest of the northern mountain, here called Bear mountain.		
"	SS. red, hard,	30	
"	Slates and shales, green,	30	
"	Shales and SS. red,	49	
"	SS. greenish gray,	19	
"	Shale, red,	202	
"	SS. green,	10	
"	SS. with pebbles, red and greenish gray,	49	
"	Shale, red,	19	
"	SS. chocolate, with quartz pebbles,	44	
"	SS. red, and red shale,	70	
"	SS. reddish brown, coarse, quartz pebbles scattered and in bands (at RR. bridge N. of Packerton.) Top part of White's No. 9,	147	
"	Shale, greenish gray,	106	
"	SS. pebbly, chocolate red, bottom of No. 9,	12	

" " gray, flaggy, pebbly, pebble streaks, ...	516	
" " red, ...	11	
" " grey, flaggy, pebbly above, ...	547	
" " grey, fine, with some shales, ...	526	
" " red, shaly, ...	47	
" " greenish, and shales, ...	160	
" " reddish, and shales, ...	37	
" " greenish gray, ...	113	
" Shale, red, ...	57	
" SS. greenish gray, siliceous, ...	225	
" Shale, red, ...	19	
" SS. and shale, greenish, ...	111	
" " " " reddish, ...	37	
" " " " greenish, ...	19	
" " " " red; with one *limy bed*, ...	56	
" " greenish gray, ...	37	
" Shale, red, ...	92	
" SS. greenish gray, ...	139	
" SS. and shale, red, ...	19	
" Shale, green, ...	37	
" " red, ...	92	
" SS. green, ...	46	
" Shale, red, ...	307	
" " " and green, variegated, ...	84	
" " " (opposite Packerton offices), ...	310	
" SS. and shale, greenish gray, ...	20	
" Shales, red, ...	105	
" " green, ...	15	
" " red, ...	25	
" " green, ...	20	
" " red, ...	60	
" " grayish green, ...	42	
" " red with thin green bands, ...	548	
" SS. greenish gray, ...	110	
" " red, ...	6	
" " greenish gray, ...	15	
" " red, ...	5	
" " greenish gray (White's No. 32), ...	1155	
" " red and green, ...	104	
" " red, some green, ...	312	7145′
VIII g. CHEMUNG and PORTAGE FLAGS and SHALES, . .		1292′
VIII e. Genesee black shales, ... visible,		290

Total thickness of section, 13,148′.

White's Section on the Lehigh.

X. POCONO.

1. Conglomerate, very massive, whitish, large pebbles, ...	50
2. Shales, sandy, greenish-gray, ...	50
3. Conglom. dark gray, large pebbles, *coaly streaks*, .	50
4. Shales, sandy, buffish gray, ...	120

5.	Sandstones, dark buffish; some shales,	430
6.	*Mt. Pleasant conglomerate,*	50=750′

IX. CATSKILL.

7.	*Mt. Pleasant* red shale,	40
	" red sandstone,	40
	" red and green shales,	60
	" red conglomerate,	10
	" red shale,	250
	" red shale and sandstone,	100
8.	" reddish sands and shales,	200
9.	*Cherry Ridge conglomerate,*	40
	" greenish sandstones,	110
	" conglomerate (L. V. RR. bridge),	50
10.	*Cherry Ridge red shale group.* (concealed),	200
11.	" conglomerate, gray,	60
12.	" sandstone flags, greenish,	350
13.	" sandstone, gray (two or three red beds),	175
14.	" *Calcareous breccia,*	2
15.	" sandstone, gray, massive (a few red),	120
16.	" shales, red, sandy,	30
17.	" sandstone, very massive, green-gray,	120
18.	" shales, red, sandy,	60
19.	*Honesdale sandstone,* gray, some pebbles,	165
20.	" *Calcareous breccia,*	8
21.	" sandstone, greenish gray,	180
22.	" *Calcareous breccia,*	2
23.	" sandstone, greenish gray,	60
24.	" " variegated, green and red,	60
25.	" shale, red, sandy,	30
26.	" *Calcareous breccia*	2
27.	" sandstone, reddish gray, some pebbles,	60
28.	" shales and sandstones, red,	120
29.	" sandstone, gray (very little red),	150
30.	" " red, and grayish green,	150
31.	*Montrose red shale; all red* except a few thin streaks of gray,	2000
32.	*Delaware flags,* no red at all,	1200
33.	*New Milford, red* and *gray* shales and sandstones; more red than gray in the whole mass,	700
34.	*Starucca flags,* greenish gray; now and then red beds (the lowest being 120′ above the bottom), about	600=7544′

35.	VIII g. CHEMUNG sandstone with some shale; bluish gray and olive, sparingly fossiliferous,	1200′
36.	VIII e. GENESEE, dark fissile shales,	200′
37.	VIII c. HAMILTON gray sandy shales; fossils,	760′
38.	VIII b. MARCELLUS shales, mostly dark,	800′

Comparison of sections.

Two intermediate sections between the Delaware and Lehigh were measured by Prof. White, one at Broadheadsville, the other at Stroudsburg, but the dips being low, and almost flat along the northern parts of the section lines the measurements will not compare for accuracy with the Lehigh section. They are given in G6, p. 81. Their comparison is very interesting :—

	Lehigh.	*Broadheadsville.*	*Stroudsburg.*	*Delawrre.*
Catskill, ...	7544	5325	4200	3430
Chemung, . .	1200	1600	1750	1850
	8744	6925	5950	5280

But in the absence of similar sections made by the same observer at the Little Schuylkill, the Schuylkill and the Swatara, it would be a very unsatisfactory speculation how far the increase westward is due to the upturn of dip from horizontal to vertical in that direction, and how far to a real increase of the quantities of matter deposited along the line of this southern outcrop westward. We shall see in the next chapter how a decrease of deposits northward takes place in areas of considerably steep dips.

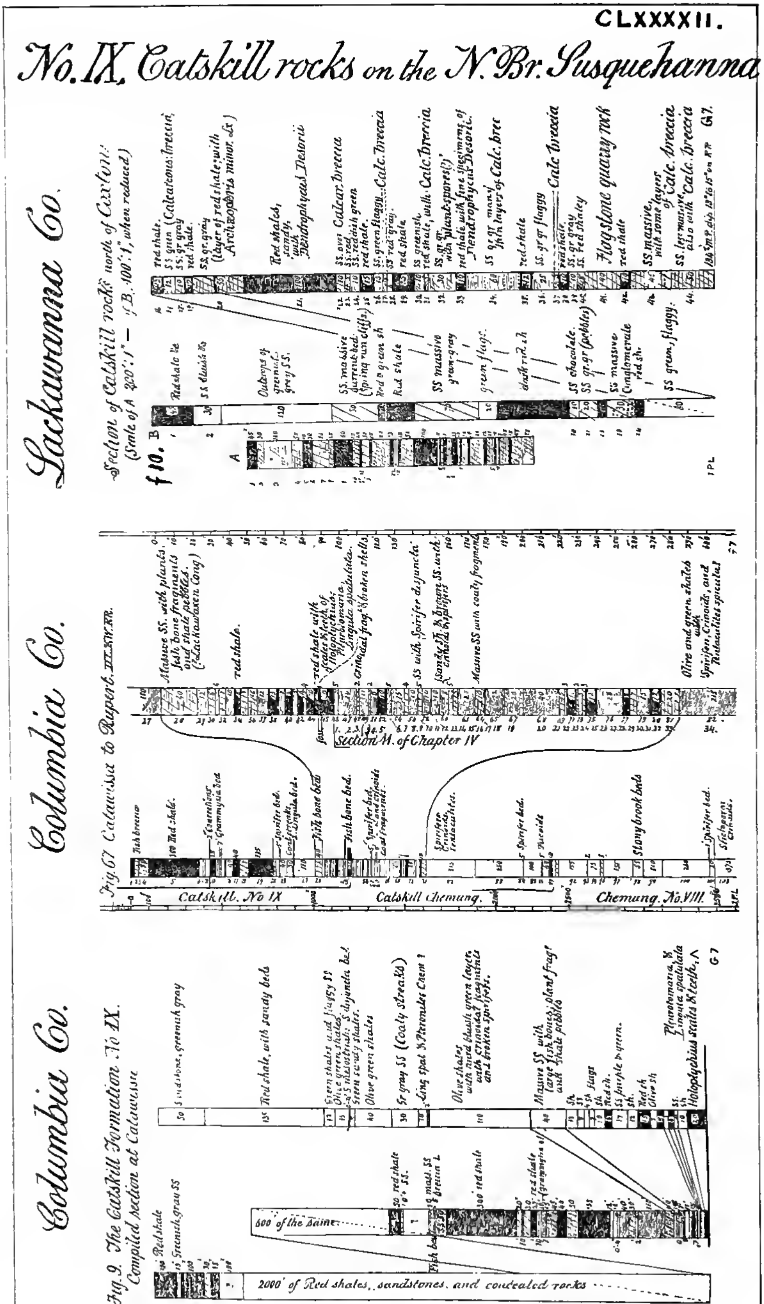
Topography of the double crested mountain.

The trough between the two crests of the mountain is made by the *Mt. Pleasant red shale* mass 700′ thick ; the northern crest by the *Mt. Pleasant conglomerate* and overlying sandstone mass, 480′ thick ; and the southern crest by the three *Cherry hill conglomerates* and included strata, 460′ thick. The series of *Calcareous breccia* locked up in the softer red sandstones and red, green and gray shales from No. 14 down to No. 30 make the southern slope of the mountain. The *Montrose red shale* mass, No. 31, 2000′ thick, makes the elevated little valley or terrace at the foot of the southern slope ; and the *Delaware flagstone* series, etc, No. 32, downwards, make the Little mountain, its southern foot slope being Chemung. This Little mountain runs on west into middle Pennsylvania where the slanting dips turn it into the terrace of IX as before described.

Fossils in Catskill rocks.

Fish fragments (if they be such) in the calcareous breccias are the only evidences of animal life ; for Prof. White could not find a single molluscan shell in this great mass of sediments anywhere in the three counties. *Plant remains* are also rare. Pieces of stems are often seen, but so spoiled by long floating in sea water that their species cannot be made out. At one point only, in the cut of the D. L. & W. RR. a short distance below Henryville, and near the base of the *Montrose red shale*, he found great numbers of the fine fern *Archæopteris jacksoni.**

* This dearth of life was probably due to the sea water being charged with sulphate of iron (copperas), the slow per-oxidation of which has reddened so much of the whole formation. Not a single bed of *iron ore* has been seen; but the quantity of iron distributed through these strata may be estimated from two analyses of red shale of Monroe Co. by McCreath and Stinson :—Silica, 61, 63 ; alumina, 19, 19 ; sesquioxide of iron, 7.7, 8.0 ; lime, 0.3, 0.3 ; magnesia, 1.5, 1.7 ; phosphorus, 0.003, 0.051 ; water, 3.8, 3.6.


CLXXXII.
No. IX. Catskill rocks on the N. Br. Susquehanna
Lackawanna Co.
Section of Catskill rocks north of Carbon
Columbia Co.
Fig. 67 Catawissa to Rupert.
Section M. of Chapter IV
Catskill. No IX
Catskill Chemung.
Chemung. No. VIII.
Columbia Co.
Fig. 9. The Catskill Formation No IX.
Compiled section at Catawissa
600' of the Same
2000' of Red shales, sandstones, and concealed rocks

CHAPTER CIX.

IX. Catskill on the Susquehanna and Juniata.

The southern outcrop retains its thickness through Schuylkill, Lebanon, Dauphin, and Perry counties. But when the outcrop is followed around the western ends of the Anthracite coal fields, northward, zigzaging up the Susquehanna river, through Northumberland and Columbia counties into Luzerne and Lackawanna counties, it decreases in thickness while it retains its general character.* Ascending the Juniata into Huntingdon, we see it around the Broad Top coal basin and along the Allegheny mountain diminishing to one-half and one-third of its thickness in Perry county. Back of the Allegheny mountain in the northern and western counties it grows thinner and thinner until in the oil wells it becomes very obscure.

IX. Catskill in Perry county.

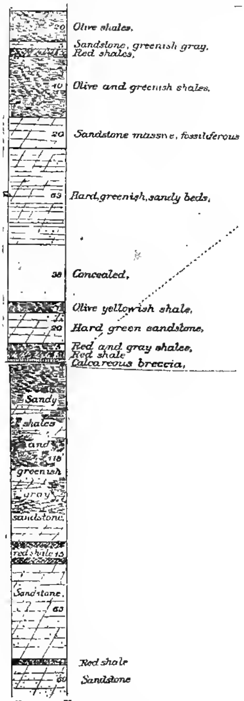
Prof. Claypole estimates the thickness of the whole Catskill mass surrounding the Cove and Buffalo mountains at 6000 feet, and the overlying Pocono at 2000 feet. As the dips are gentle or moderate both ways the breadth of the Catskill outcrop is very great, and is increased by numerous small rolls, especially in Wheatfield, Penn and Watts townships. Fine sections can be examined along the banks of the Juniata river above its mouth, Chemung upper strata being included in the wrinkles. The limit between the two formations is not well defined, for the red color gradually comes in as we ascend from the Chemung into the Catskill while the peculiar thin fine-grained sandstones gradually disappear; but there is no mistaking the rather sudden commencement of the great mass of red shales and sandstones; and shortly above this the *fish beds* begin to ap-

* White's measurements are 4500′ in Northumberland, 4400 in the Catawissa gap, 4330 at Catawissa, 2105 on Fishing Creek, 1800 in Wyoming, etc. (G7, Index, p. 437).

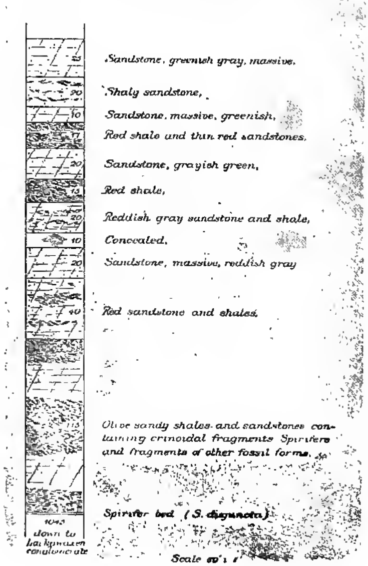
CLXXXIII.

No IX, Catskill in Huntingdon and Perry.

Red beds in Catskill formation No. IX.



Middle measures of Catskill No. IX.



Catskill in Cove synclinal in Perry Co.

Fig. 1. Section AB across Carroll township

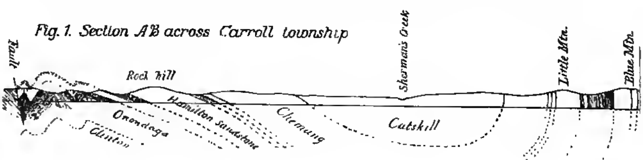


Fig 3

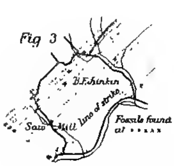
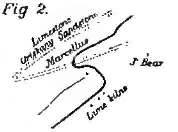


Fig 2.



pear, which have been described in a previous chapter. (F2, 72). The Kings Mill and Dellville sandstones have been discussed. Casts and impressions of shells sometimes found in the red rocks show that the lower Catskill age was not destitute of creatures, but there remains have been dissolved away. Chemung shell-casts prove this by the fact that both the inner and outer marks of the shell on the two surfaces remain. The upper part of the Catskill formation consists of hard and often massive sandrock strata which make the bold terrace which surrounds the ends and follows the sides of the two synclinal mountains. On the east bank of the Susquehanna the Northern Central RR. has cut a grand exposure of them. On the west bank they make Duncannon Hill, a favorite resort of lovers of fine scenery. A mile west, Sherman's creek makes a narrow and picturesque gorge through them. They run on west as Pine Hill, which after turning the mountain returns east as The Ridge, with overturned dips to the south. It is isolated from the mountain by softer strata (*Mt. Pleasant red shale* of White) between the Catskill and Pocono masses (F2, 78). Near Liverpool up the Susquehanna river, the *Delaware flagstone series* furnishes good quarries (p.244). The Catskill outcrop reaches from a point 2 m. N. of Haldeman's Island to the base of Peters mountain, a breadth of nearly 4 milles (p. 384. See also reduced figure of the synclinal section on plate CLXXXXII above).

Catskill iron ore in Perry County.

As for minerals in the Catskill formation there are none, except a seam or two of *red specular iron ore*, of good weight and excellent quality, which traverse the rocks in several parts of Perry county, especially in the southern (Oakgrove) synclinal, but not exceeding 4 inches in thickness, lying between hard sandstone strata, and of course worthless for mining. Geologically this ore is exceedingly interesting, and when analyzed by Mr. McCreath its composition proved to be as follows:—Sesq. iron, 86.0; Sesq. manganese, 0.072; Alumina, 1.85; Lime, 0.75; Magnesia, 0.4; Sulp. acid, 0.04; Phosphoric acid, 0.082; Water and organic matter 0.97 ; Siliceous matter, 9.83.=Metallic iron 60, 2, etc. F2, 102).

IX. Catskill on the N. Branch Susquehanna.

The gap which Catawissa creek makes through Nescopec mountain near Mainville gives a fine section of Pocono and Pocono-Catskill rocks (G7, 51). The railroad cuttings along the river at Catawissa and between it and Bloomsburg gives an almost complete section of the Catskill, Catskill-Chemung, and Chemung rocks down into the Marcellus, an exposure of 7237′ (G7, 287). Combining the two we have the following general section :—

Catawissa Section.

XI.	*Mauch chunk red shale.*	
X.	*Pocono* SS. coarse, gray, yellowish,	30
"	concealed,	250
"	SS. massive, whitish ; some conglomerate,	300—580
X-IX.	SS. shales, etc., gray,	300
"	SS. gray, passing down into reddish,	75—375
IX.	*Catskill red shale,*	100
"	SS. greenish gray,	15
"	*Red shale,* with some thin green sand,	100
"	SS. greenish gray and yellow,	30
"	*Red shale,*	35
"	concealed,	100
"	Red shales, sandstones, and concealed,	2000
"	*Red shales,* with greenish beds, concealed,	600
"	*Red shales,*	50
"	SS. greenish, massive, visible,	10
"	Concealed,	110
"	SS. massive, greenish,	20
"	*Calcareous brecca ; fish bed,*	5
"	SS. greenish,	50
"	*Red shales* somewhat sandy,	300
"	SS. greenish,	20
"	Shales green, sandy,	10
"	SS. greenish, massive,	30
"	*Red shales* massive,	27
"	Olive shales,	10
"	SS. greenish,	10
"	SS. shaly, with *Grammysia elliptica?*	7*

* Prof. White remarks that many geologists would stop the Catskill here and call all the 700′ of rocks from this *Grammysia bed* downward Chemung, because the *Grammysia* is considered a Chemung fossil, and other Chemung fossils occur at various horizons in the 700′. But on the other

"	Olive green sandy shales,	15
"	SS. shaly, green,	45
"	*Red shale,*	40
"	S. S. greenish,	50
"	*Red shale;* some sandy beds,	135*
"	Green shales and flags,	12
"	Olive shales,	15
"	*Spirifer* bed, (*S. mesocostalis* and *S. disjuncta* in large numbers,	$\frac{1}{3}$
"	Green sandy shales,	5
"	Olive shales,	40
"	SS. greenish, hard, (*Coaly streaks*),	30
"	Olive shales, with *Lingula spatulata, Pteronites chemungensis?* and others poorly preserved,	10
"	*Red shale,* sandy,	2
"	Olive shales; thin hard layers with broken *Spirifers* and *Crinoids,*	110
"	*Lackawaxen conglomerate;* quite massive sandstone beds holding *slate pebbles, plant rags,* and large *fish bones,*	40†
"	greenish sandy shales,	12
"	SS. green,	8
"	Olive shales,	4
"	SS. flags greenish	7
"	greenish shales,	10
"	*Red shale,* sandy,	8
"	SS. purplish and green,	17
"	Olive green shales,	12

hand *Holoptychius americanus* is considered a Catskill fish, and it is found at the bottom of the 700′. He prefers to say that many Chemung shells lived on into the Catskill age. The fact is, the whole Chemung mass is merely a middle division of the great Catskill mass, for in New York the *Oneonta formation* underneath the Chemung is as much Catskill as the mass above the Chemung. There are no lines to be drawn, in fact, there are no planes of nonconformability discoverable. The deposits of the whole Devonian system went on regularly, bed upon bed, and our division names are mere names of convenience and nothing more; and very rudely applicable at that. Another evidence of this fact is found in the 1000′ of *red shales*, etc. underneath the 4330′ assigned by White to the Catskill proper.

*This mass seems the bottom of the *Montrose red shale* formation of Wayne county, which may perhaps include 1000′ of the strata above. At the base of this 135′ mass of red shale occur, on Catawissa, creek near the Maine township line, great numbers of the curious seaweed *Dendrophycus desorii*, Lesquereux, figured on plate 23 of Rogers' Geology of Pennsylvania, Vol 2, part 2 (G7, 60).

† Some of these fish bones are more than an inch in diameter. Four miles below Catawissa, opposite the railway water tank, this stratum becomes a very coarse quartz *conglomerate* with some pebbles 2 inches in diameter, rather flattish, and very large fish bones in considerable numbers. The Venango First Oil Sand in Warren county, a coarse fish bone conglomerate, seems to lie at about the same geological horizon (White, G7, 59).

"	*Red shale*, sandy,	13	
"	Olive shales,	7	
"	*Red shale*,	8	
"	Green shales, sandy,	5	
"	*Red shale*,	6	
"	SS. brown,	4	
"	Olive shale,	10	
"	*Red shale*, with *Lingulo spatulata*, *Pleurotomaria*——? and *Holoptychius scales and teeth*,	20*	4330

IX-VIII, *Transition beds;* section continued:

"	Green sandy shale,	5
"	Olive green shale,	20
"	Brown sand, broken *shells*, *crinoids*,	2
"	Olive shale,	8
"	*Purple shale*,	10
"	Olive shale,	5
"	Brown sandstone, flaggy,	19
"	Olive shale,	10
"	Brown hard sand, *Sp. disjuncta*,	5
"	Olive shale,	20
"	Shales and flags, *Sp. meso.* and *crinoids*,	8
"	Olive shales,	5
"	Green sandstone,	5
"	Olive shales,	20
"	SS. massive (with *Coaly fragments*),	10
"	Dark gray sandy shales,	22
"	Green sands and shales,	20
"	Olive and brown shales,	40
"	Greenish sandstone,	5
"	Olive shale,	3
"	*Red shale*,	10
"	*Red sandstone*,	2
"	Olive shales	5
"	*Red sandstone*,	3
"	*Red shale*,	12
"	Olive shale,	28
"	*Red shale*,	8
"	Gray sandstone,	7
"	Olive shale,	15
"	*Dark red shale*,	12
"	SS. massive, greenish,	20
"	Olive shaly sandstone; with some brown beds, containing *Spirifera*, *Tentaculites spiculus?* and crinoid fragments,	215
"	Olive sandy shales,	250
"	Brown sandy shales filled a coarse *Spirifer* (*disjuncta?*)	5
"	Greenish sandy beds,	100
"	Sandstone, with many *fucoids*,	5

*The fish remains are badly preserved. One tooth got broken in being extracted from the rock; but as it lay in the rock it seemed to Prof. White to represent exactly the tooth of *Holoptychius americanus*

" Concealed,	40	
" Olive shales,	5	
" *Lowest purple red shale;* exposed at roadside near mouth of little run, 280 rods north from Catawissa station: assumed base of White's transition Catskill-Chemung group,	10*	1007

IX. Coxton section, Luzerne Co.

The Catskill rises from under the Eastern Middle Anthracite coal field of Hazelton and Eckley, northwards, as the terrace of Nescopec mountain, on the south side of the great Montour anticlinal,—descends on the other side of it northwards as the terrace of Wyoming mountain,—passes beneath the Northern Anthracite field, at a depth of 6000′ or 7000′ under Wilkesbarre,—and rises northward to make the terrace Schickshinny mountain at Coxton (above Pittston), and then gradually flattens northwards upon the broad flat back of the Watsontown (or Milton) anticlinal, to descend with scarcely any perceptible dip northward into the front flank of the Great North (Allegheny) mountain. The N. Br. Susquehanna crossing the Watsontown anticlinal shows about 1231′ of Catskill upper and middle strata. About 500′ (or less) of lower strata are concealed by surface rocks from the 174th mile post of the Lehigh Valley railroad northward to the center of the arch of the anticlinal. If this estimate be correct the Catskill thins down northeastward from 4330′ at Catawissa to only about 1700′ at Coxton.—The Pocono thins in the same distance and direction from 955′ (including Pocono-Catskill beds, 375′) to only 353′.

Campbell's Ledge and Coxton section.

XII. Pottsville conglomerate, Campbell's Ledge,		—
XI. Mauch Chunk red shale,		150
X. Pocono Sandstone, massive, gray,	100	
" Conglomerate with slate and sandstone breccia,	2	

*The lowest red bed (not certainly the same one of course) seen by White at various places in his extensive district lies at various heights from a minimum of 2200′ to a maximum of 2500′ above the top of the Hamilton (G7, 64). This Transition Series holds some acknowledged Chemung shells, but all of them forms which elsewhere in the State survive with slight changes into the Pocono (sub-carboniferous) formation. The red shales or sandstone beds have a characteristic Catskill aspect (G7, 65).

"	Greenish shale,	1	
"	Sandstone, gray, massive,	55	
"	Concealed,	50	
"	*Red shale*, sandy, . . . seen	10	
"	Concealed,	5	
"	Conglomerate, coarse, whitish,	45	
"	Sandstone, gray, a few pebbles,	30	
"	Sandstone, shaly; and concealed beds,	25	
"	Sandstone; large quartz pebbles at base,	30	353
IX.	CATSKILL *Red shales* and concealed,	45	
"	Sandstone, blue-green, green-gray,	30	
"	Concealed; many sand crops,	120	
"	Sandstone; cliffs at Spring run,	50	
"	*Red and green shales*,	10	
"	*Red shale*,	30	
"	Sandstone, massive, pebbly in lower half,	70	
"	Sandstone, green flags,	20	
"	*Red shale* (dark red),	80	
"	*Sandstone*, chocolate red,	10	
"	" gray; some pebbles,	20	
"	*Red shale*, sandy,	10	
"	Sandstone, lower part full of large quartz pebbles,	30	
"	*Red shale*,	10	
"	Sandstone, green, flaggy; to 173 M. P.,	80	
"	Red shale, sandy,	13	
"	Sandstone; much *calc. breccia*,	12	
"	" greenish gray,	10	
"	*Red shale*,	10	
"	Sandstone, greenish gray; near the middle a thin *red shale* layer holding *Archæopteris minor*,	55	
"	*Montrose red shales*, with badly preserved specimens of *Dendrophycus desorii*,	100*	
"	*Calcareous breccia* (sandstone top),	10	
"	Sandstone, *red*,	5	
"	Flags, green,	10	
"	*Red shale*,	15	
"	Flags, green,	10	
"	*Calcareous breccia*,	5	
"	Sandstone, reddish gray,	6	
"	Red shale, sandy,	25	
"	Sandsone, greenish,	10	

*This 100′ undoubtedly represents part at least of the Montrose group.—*Marine plants* like *Buthotrephis*, in considerable numbers and varieties, occur from this horizon down nearly to the bottom rocks of the section.—The fine fern *Archæopteris hybernica*, of which splendid specimens have been found in the Meshoppen flagstone quarries high up the river, ought to exist in strata lying concealed not far below the lowest exposed bed in this section. (White, G7, 62, quoting Mr. R. D. Lacoe of Pittston, whose fine private cabinet of fossil plants and personal acquaintance and coöperation with Leo Lesquereux have been of such great benefit to the geological survey of our State.)

"	*Red shale* and *Calcareous breccia*,	5	
"	Sandstone, greenish gray (oolitic),	30*	
"	*Red shale*, with fine specimens of *Dendrophycus desorii*,	10	
"	Sandstone; many thin partings of *Calcareous breccia*,	60	
"	*Red shale*,	12	
"	Flags, greenish,	25	
"	*Calcareous breccia*,	5	
"	*Red shale*, sandy,	10	
"	Sandstone, greenish,	10	
"	" *red*, shaly,	8	
"	Flags, greenish gray (QUARRIES),	40	
"	Red shale, sandy,	10	
"	Sandstone, massive, greenish; some layers of *Calcareous breccia*,	45	
"	Sandstone, less massive; some *Calcareous breccia* layers, rising from RR. track, M. P. 174; dip S. 13° to 15°,	50	1231′
"	Lower Catskill strata concealed,	500?	1731?

The above will suffice to display the Catskill formation in this district. For many local sections the reader will refer to Prof. White's voluminous report G7, 1885.

IX. Catskill around Broad Top in Huntingdon, Bedford and Fulton counties.

Red shale predominates in the upper and middle two-thirds of the formation in all the sections exposed by the bends of the Raystown Branch of the Juniata cutting into the Catskill terrace of Terrace mountain, and by the streams which flow down from the Broad Top coal region through gaps in the mountain. This is on the west.†

* This set of beds contains agglomerations of small egg-like bodies which Prof. Claypole suggests are *spores of plants* (White, G7, 61).

† The Catskill terrace of Terrace mountain is a striking object in the landscape but differs entirely from the Oneida terrace of Tussey mountain, already described. The mountain has a sharp crest of massive conglomeritic Pocono sandstone; like the Medina crest of Tussey. But there is no such mass of hard sandstone in the Catskill as the Oneida; consequently there is no sharp bold crest to its terrace; no double headed ravines behind the terrace. On the contrary the Catskill mass is merely an alternation of comparatively thin masses of softer sandstones with masses of red and green shales. Terrace mountain therefore exhibits to the eye of spectator a steep upper slope, a steep lower slope, and a gentle middle slope, made by the outcrops of somewhat less refractory beds. The mountain has a steep slope near the top, then a flatter place, and then another steep slope lower down, ending in a long gentle slope to its foot.—The dips in Sideling hill being much steeper and the soft red rocks being less in proportion its terrace almost vanishes from view.

On the east, in the long range of Sideling hill, the formation is well exposed only in one gap made through it by a head branch of Aughwick creek; and here there is a far greater proportion of gray shales and sandstones than of reds, in consequence of which the groupings of Pocono and Catskill by White on the east and by Ashburner and Billin on the west differ, although the thickness of both together is the same on both sides of the Broad Top synclinal thus:—

X.	Pocono in Terrace Mt. 1132′	. .	in Sideling hill 2133′
IX.	Catskill " " " 3600′	. . .	" " " 2680′

The whole belt of Catskill outcrop is a beautiful farming country, the sandstones weathering easily and making with the red shales a mixed soil exceedingly fertile, especially when properly limed. The interstratification of sands and shales is well shown in the great bend of the river opposite the mouth of Coffee run, the top of the section being on the foot slope of the mountain. (See T3, plate 16, p. 82, reduced on page plate —— of this volume.)

IX. Coffee run section, Huntingdon Co.

X.	POCONO SANDSTONE of Terrace mountain.		
IX.	Catskill upper rocks (here concealed), . .	700	
"	Red shales predominating in, ...	1270	
"	Sandstone, greenish, massive, ...	10	
"	Concealed interval, ...	15	
"	Sandstone reddish, massive, ...	10	
"	Red shale, with some thin green sands, ...	115	
"	Sandstone, greenish gray, massive, . . .	25	
"	" shaly, ...	20	
"	" massive, ...	10	
"	Red shale and thin red sandstones, . . .	17	
"	Sandstone greenish, ...	20	
"	Red shale, ...	15	
"	Sandstone, reddish, and red shale, ...	20	
"	Interval concealed, ...	10	
"	Sandstone, reddish, massive, ...	20	
"	" red and red shale, ...	40	
"	Olive sandy shales and sandstones with *Spirifera disjuncta?* and other broken up forms and crinoids, ...	115	
"	*Spirifera disjuncta* bed	1	
"	Olive and greenish shales (with red shales at the bottom), partly concealed, ...	300	
"	Sandstones and shales, greenish, partly concealed,	220	
"	" green, with olive and red shales, . .	525	3478

VIII.	CHEMUNG UPPER (LACK.) CONGLOMERATE,	10	
"	Sandstone, greenish, rather massive, ...	15	
"	Red shales in a concealed interval, ...	85	110*

Fossil remains in the upper 2500′ of the Catskill column are very scarce or absent; only a few fragments are seen, and not to be specifically recognized; and occasionally a *fish scale* or broken fish bone. The *Calcareous breccias* are seldom seen, and then only 1′ or 2′ thick. *Ripple marked* bed plate surfaces are very abundant, especially in the red shale layers.

A red specular iron ore bed, only one or two inches thick, crops out near Haun's bridge about 1400′ above the Lackawaxen conglomerate and recalls one or two similar very remarkable beds in the Catskill in Perry county. See above.

The lower 1000′ of Catskill strata overlying the Lack. conglomerate are on the contrary very fossiliferous; some of the common uppper Chemung types of brachiopod and lamellibranch shells being very abundant, and large collections may be made along the north bank of the river just below the bridge, thus:—

IX. Haun's Bridge group. T3, 194.

X.	POCONO and TRANSITION beds mostly red shale.	
IX.	CATSKILL *red beds;* (specular iron ore 1600 below top;) practically the whole of this group is red, . . .	2200
"	Sandstones, green and reddish brown; red shale alternations; many fossils up to the highest beds of the group, ...	1325
"	Lackawaxen conglomerate (fish), ...	10

* This is the lowest red bed seen, and is assumed by White as the base of his Catskill proper in all his five measured sections (measured by pacing across the outcrop and calculating thickness from dip) viz: (1) here at Coffee Run, 3588′; (2) along Trough creek and James creek in Todd township, 3942′; (3) a mile further east, 3650′;—(4) along south bank of Juniata, 3420′;—and (5) on the north bank in Henderson county, 3620′;—average of all five, 3625′. The top of the sections in all five sections taken at say 1100′ beneath the bottom of the Mauch Chunk formation No. XI (T3, p. 90). The third and fifth of the sections are given in his detailed reports of Penn and Henderson counties (T3, 175, 263).—Of course these thicknesses of IX harmonize neither with those of Ashburner and Billin in Sideling hill, nor with those of Stevenson along Terrace mountain in Bedford county, as will be seen in the text below.

IX. Catskill in Sideling Hill.

The strata along the eastern front of the mountain in Smith's valley, Huntingdon county, were carefully measured in 1874–5 by Ashburner and Billin ; the top of their section being the base layer of Pocono olive shales and sandstones, 777′ *geologically* beneath the *Cypricardia* and *Orthis shale bed* at the east mouth of the railway tunnel. But as their Lower Pocono strata are evidently the same (excepting in color) with White's Terrace mountain uppermost Catskill mass, these strata will be included in the following section (T3, 87, 95):

IX. Sideling Hill section.

X–IX.	LOWER POCONO OF UPPER CATSKILL.		
"	Sandstone slaty, dark blue, with fine white shale,	22	
"	Shales, gray, green and yellow,	25	
"	*Cypricardia* and *Orthis* green shale,	5	
"	Shales, softer, outside the tunnel,	25	
"	Sandstones *reddish* gray, coarse, hard, alternating with shales,	165	
"	" coarse yellow iron-stained,	12	
"	" shaly, yellow gray and green,	44	
"	Shales soft, gray flags, micaceous,	50	
"	Flags, olive and green-gray ; *iron balls*,	42	
"	Sandstones soft, green and olive, alternating with yellow flags, and with hard iron-specked massive layers,	440	830
IX.	*Red shales and sandstones*, with gray and white sandstones ; not clearly seen,	175	
"	*Red shales*, soft and bright, alternating with greenish gray slaty sandstones,	100	
"	*Red shales*, *Red sandstone*, and reddish gray, coarse massive sandstones,	125	
"	*Iron ore*, very sandy brown hematite,	—*	
"	*Red shales* and *red flags*, alternating with massive shaly yellow grey and white sandstones,	1520	
"	*Red shales*, sandy and clayed ; lower part *ripple marked* with *seaweed* impressions,	270	
"	*Red sandstone* massive, and *red shale* ; brown sandstones towards the bottom,	140	

* This worthless bed of limonite may have some relation to the specular ore bed of the Haun's bridge section, given just above, and even to the Perry Co. specular ore beds. It would be a most extraordinary and curiously interesting discovery if such a geological horizon over so large an area could be demonstrated.

"	*Red* and gray shales, and sandstones massive, gray, containing very small *coal seams*, ...	290	
"	Shales, sandy, yellow, with friable *red shale*, *stained with pitch*, and brownish sandstones,	60*	2680
IX-VIII.	Shales; *Lepidodendra* and *calamites*, . .	8	
"	Red sand and shale ripple marked, . . .	18	
"	Olive sand and shale, ...	10	
"	Gray sand and shale; lower part fossiliferous,	15	
"	Red sand and shale alternations	25	
"	Green fossil shale, ...	1	
"	*Iron ore* bed, *Spir. disj.* and *Rynch.*, . .	4″ to 1	
"	Green fissile shale, with two inch flags of sandstone; upper sides ripple marked; under sides fucoid impressions, ...	3	
"	Sandstone brownish; *Sp. disjuncta*, . .	1	
"	Shale, whitish; plant impressions, . .	1	
"	Sandstone yellowish red, ...	5	
"	Red shale, ...	3	
VIII.	Sandstones and shales, olive and brown (some red shale) partly concealed, ...	245	
"	LACKAWAXEN CONGLOMERATE (?).		
"	Massive sandstone, dark grey, iron-specked, alternating with reddish grey flags, ...	15†	336

IX. Catskill in Fulton and Bedford Cos.

Prof. Stevenson says: "The Catskill is a mass of shale and sandstone with no definite succession of beds. A section obtained at one locality would be of little service four or five miles away, as the sandstones and shales replace each other suddenly." The group shows very marked decrease in thickness as it goes westward. On the pike in Fulton county between Patterson's run and Scrub ridge (X) are exposures of Catskill, 3900′; on Yellow creek in E. Bedford Co. about 3000′; on Wills creek in S. W. Bedford Co. only 1980′; on the west line of Somerset county, in Laurel ridge gap (east dipping) only some thin brownish micaceous flags; on the west dip, and in the Fayette and Westmoreland Co. gaps, all trace of the formation is lost.

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*In these beds (60′) were a few *fish bones* and *fish scale* fragments, and their presence may suggest an explanation of the slight pitchy coating which some of the surfaces exhibit. Ashburner's rocks beneath these beds form the north slope of Clear ridge in Smith's valley, the crest of which is made by what is supposed to be White's Lackawaxen conglomerate (Stevenson's Upper Chemung conglomerate). For the convenience of the reader I carry down Ashburner's section to the conglomerate (T3, 109).

† It is by no means certain that this is the L. C. Other massive sandstones occur 100′ and 300′ beneath it. Consult T3. 03.

Its composition is exceedingly variable. On the east side of Sideling hill in the middle of Fulton Co. it consists wholly of soft red shales and occasionally flags of sandstone for 1600 down from its top. Below, brownish or greenish red sandstones extend down to within 250′ of the assumed base; then come red and yellow shales.—So also in Bedford Co. between Ray's hill and the river; but the lower sandstones are more massive and less laminated. But in W. Providence where the Juniata makes two long curves the whole mass seems equally divided throughout between alternating shales and sandstones.—On the H. & B. T. RR. where it is fairly well exposed, it consists largely of blood red shales and clay-sandstones often handsomely ripple-marked. At Saxton the lower part of the formation is hidden. On Yellow creek the upper portion is hidden; but from 870′ below the lowest Pocono (X) bed this is a good exposure of 400′ of compact reddish brown sandstone beds and then 717′ of deep shales and brownish red thin flags rarely more than an inch thick.

Everywhere the Catskill sandstones are cross bedded, and many of them show a strangely *pitted* weathered surface, as if from groups of *worm borings*, to a depth of ½ to ⅛ of an inch.

Along Wills creek in west Bedford Co. there is an almost complete exposure of IX. Thin flagstones predominate in the upper part, and shales lower down, the sandstone layers becoming soft and clayey. The shales are mostly a brilliant red, with white spots. Here and there are thin grey beds.

Along the Allegheny mountain IX makes a handsome terrace, with obscure exposures; thin red flags everywhere present in the mass.

No fossils in IX; no fish; only one shell, *Amnigenia catskillensis*, from one of the highest beds on Wills creek (T2, p. 74, 75).

Two sections will suffice in this region; but they require the Pocono as well as the Catskill.

Hopewell (Yellow creek) section, Bedford Co.

X.	Pocono sandstone; average dip 53° S. E. making the crest of Terrace mountain; well exposed along the Kemble C. & I. Co.'s narrow gauge RR. at the river. Massive in upper part, growing flaggy downwards and then shaly. Contorted rock, with seams of coal, pockets of black shale; conglomeritic in upper 30,	736	
"	Shale and sandstone beds,	140	
"	Sandstone, gray to blue, mostly very hard; middle part full of plant stems, casts lined with coal-films, often replaced by pyrites, or brown hematite; beds crowded with carbonized plants; two beds of ferruginous conglomerate,	87	
"	Shale (between river bridge and creek bridge) bottom sandstone 5′ thick,	70	
"	Concealed. (Pocono base above the middle),	870	1903
IX.	Catskill sandstones, mostly laminated; some dark red, mostly greenish red; mostly pitted and worm-eaten; with some blood red shales,	400	
"	Shales at top, blood red; sandstones increase in proportion downward, laminated, brown, soft; many layers worm-eaten,	570	
"	Much red shale in concealed interval,	97	
"	Sandstone, laminated, micaceous, brown pitted,	15	
"	Concealed,	20	
"	Sandstone as above,	15	
"	Concealed,	166	
"	Shales rarely exposed. Sandstones in 10′ to 14′ beds. Red shales here and there. Higher sandstones red laminated, soft; others bluish, thin, gritty; towards bottom gray Chemung sandstones; limit not fixable,	1700	2883

The Hyndman (Wills creek) section.

XI.	SILICEOUS LIMESTONE at base.		
X.	POCONO GRAY SANDSTONE, light to dark gray and grayish-blue, irregularly bedded; some shale partings; carbonaceous shale near top,	25	
"	Shale, ferruginous,	10	
"	Sandstone, gray, micaceous below,	35	
"	Sandstone prevailing in an interval of,	650	
"	Concealed; Pocono and Catskill?	200	920
IX.	Catskill flags, cross bedded, micaceous, some shale,	15	
"	Concealed,	310	
"	Flags and red shale alternations; thin shales predominate, with red sandstones, soft micaceous ripple-marked,	1655	1980
VIII.	CHEMUNG and HAMILTON of Stevenson,		2630
VII.	ORISKANY,		—

IX. Catskill along the Allegheny Mtn.

In Blair county a measured section was made along the Pennsylvania railroad descending from the Summit tunnel to Altoona (published in F. Platt's Report T, 1881, p. 13, 14) in which XII was made 223′; XI, 283′; X, 1241′; IX, 2560′; and VIII, 6519′. But here as elsewhere the divisions between the formations are purely empirical. The Pocono, X, for 890′ down below the red shale of XI, consisting of gray shales and sandstones, can be accepted. The next 352′ have many red shale masses in it and may just as well be called Catskill as Pocono. I will therefore begin the section at the topmost red bed.

Blair county section, Platt and Sanders.

X.	POCONO gray sands and shales,		890
XI-X.	Transition beds.		
"	Brown shale,	5	
"	Red shale and slate,	20	
"	Brown sandstone,	15	
"	Gray slate,	5	
"	Red shale and slate,	20	
"	Sandstone, massive, gray,	20	
"	Red shale,	29	
"	Sandstone, gray,	38	
"	Red shale,	10	
"	Sandstone, gray, micaceous,	1	
"	*Iron ore* (with a sandstone parting, 1½″),	3	
"	Sandstone, gray, massive, false bedded,	26	
"	Red shale,	5	
"	*Iron ore,*	1½	
"	Sandstone, gray, micaceous flaggy,	14	
"	" ferruginous,	1	
"	" gray,	38	
"	Slate, gray,	7	
"	Red shale,	3	
"	Sandstone, brown,	1	
"	Red shale,	2	
"	Slate, gray,	15	
"	Sandstone, gray,	16	
"	Red shale,	12	
"	Sandstone, gray,	45	352′
IX.	CATSKILL.		
"	Red shale, 9; gray, 3; red, 15,	27	
"	Brown sandstone,	12	
"	Red shale,	25	
"	Gray sandstone,	20	
"	Red shale,	25	

"	Red sandstone in interval of,	196	
"	Concealed,	167	
"	Brown shale, 30; sandstone, 50,	80	
"	Red shale; a little olive,	35	
"	Sandstone, brownish, 30; gray, 10; brownish, 30,	70	
"	Red shale,	20	
"	Concealed (some reddish SS. and slate),	264	
"	Gray shale,	6	
"	Sandstone and red shale,	50	
"	" gray, slaty,	10	
"	Red shale and sandstone,	265	
"	Red sandstone, 20: shale, 10; sandstone,	45	
"	Red shale and sandstone,	30	
"	Red shale,	80	
"	Concealed,	305	
"	Red sandstone and gray shale,	15	
"	Red and gray shales,	22	
"	Red sandstone and shale (some gray),	19	
"	Gray shale,	20	
"	Red shale,	70	
"	Gray sandstone,	5	
"	Red shale,	40	
"	Reddish sandstone,	15	
"	Red shale (some gray sandstone),	60	
"	Gray sandstone (some red and gray shale),	25	
"	" " and gray slate,	40	
"	Concealed interval,	480	2560*

IX. Catskill in Clinton county.

The lofty lower slope of the Allegheny mountain from which the West Branch Susquehanna breaks opposite Lockhaven is carved by a succession of ravines in projecting smoothly rounded and bright red spurs of gently northwest dipping Catskill strata, mostly shales, which assume a horizontal attitude up the river at Tangascootac and Queens

*Of these 2560 only 1148 are exposed along the railroad and 1412 are concealed. Of the 1148 exposed *red shales* amount to 450; red shales and sandstones intermixed, 250; brownish sandstone and hard shales, 250; and massive gray sandrock (in beds of 5′ to 20′) 200. The four concealed intervals are no doubt occupied by soft rocks, viz: 363 near the top; 264 above the middle; 305 below the middle; and 480 at the bottom. Alternations of hard and soft layers of moderate thickness pervade the whole formation. These facts explain *the long slope of the lower terrace spurs* extending down to the foothills of Chemung in the Tuckahoe or Bald Eagle valley. No useful minerals are known.

run, and then roll up and down in a series of shallow basins and gentle arches across which the river has cut its channel nearly 1000 feet deep, with very steep side walls, set with low cliffs at various heights, and bolder cliffs of Pocono gray sandstone along the top. All the side valleys and ravines exhibit the same features, and afford innumerable opportunities for studying and measuring the Catskill strata. The scenery is extraordinarily picturesque. Vistas of lofty spurs and angles of the plateau, projecting between the main valley and its side branches, open and change before the traveler's eye.

At Queens run (Farrandsville) a fine exposure of red shales and red sandstones, in nearly equal proportions, and 2106′ thick, shows that 90 per cent. of the mass is red.

The formation however thins northwestward (up river) so rapidly that at Hyners station, only 13 miles distant, the same strata measure only 826′; a rate of thinning equal to 100′ per mile; so that if the base plane were supposed to be horizontal the top plane of the formation would have a down grade of 1°.

Were this decline constant and regular it would bring the formation to a knife-edge 8 miles further; *i. e.* a few miles northwest of Renovo; and we should see no Catskill outcrops in Potter and Cameron counties. But in reality the Susquehanna, Sinnemahoning and Kettle Creek valley gorges almost to their heads have walls of nearly horizontal red strata which the first survey of the state took for granted were Catskill. Dr. Chance's survey in 1879 made it probable that the red cliffs and slopes further up these rivers are rather outcrops of higher Pocono strata which have changed their color from gray to red in this region.

Chance's theory is that the red Catskill beds were deposited on a sloping Chemung shore which settled steadily during that and the succeeding ages; so that the red color marks higher and higher strata going westward; and instead of being confined to the Catskill and Catskill-Chemung formations, as at Farrandsville (Queens run), invades the lower division of the Pocono formation, while the underlying Catskill thins away and disappears.*

I will only add his two detailed sections at Farrandsville (Queens run) and at Hyner, as fair types of the formation along the face of the Allegheny mountain, and in the back country up the river gorges; the reader being left to compare them with sections in Blair and Huntingdon counties already given.

Farrandsville section. (G4, 125.)

XIII.	Lower productive coal measures,	86	
XII.	Pottsville conglomerate,	129	
XI.	Mauch chunk red shale,	100	
X.	POCONO sandstone,	15	
"	*Limestone*,	3	
"	Sandstone,	70	
"	Concealed (one red shale bed seen),	60	
"	Sandstone (one concealed slate 3″)	80	
"	Concealed,	65	
"	Sandstone, gray, hard, massive,	5	
"	Concealed,	40	
"	Sandstone, gray, hard,	35	
"	" coarse, gray (two pebbly layers),	25	
"	*Red shale*, soft,	20	
"	Sandstone, gray, and shale alternation,	68	
"	" hard, gray, massive,	47	
"	" flags, greenish gray, with shales,	59	
"	Shales *red* 5, olive 8, *red* 3,	16	
"	Sandstone flags with olive and dark shales,	41	
"	Shales (a few *red* layers),	71	
"	Sandstone gray (upper streaks of red),	45	
"	Shales olive (some sandy),	20	
"	Sandstone, hard, gray,	20	
"	Concealed,	285	
"	Sandstone, reddish, greenish (shale partings),	50	1175
IX.	CATSKILL *red shale*,	10	
"	Sandstone, hard, massive, reddish and greenish gray (some red),	95	
"	Sandstone greenish gray; *red shale* partings,	30	
"	*Red shale* soft,	53	
"	Red sandstone, hard, massive, micaceous (one thin red shale),	20	
"	*Red shale* (one massive red sandstone),	131	
"	Red and greenish gray, hard massive,	30	
"	*Red shale*, partly concealed,	56	
"	Red sandstone, some grayish red,	32	
"	*Red shale* and sandstone (in interval),	73	

*He gives a fine page plate illustration of this theory in his report G4, p. 115, which will be used in the description of the Pocono formation in this final report, Vol. III, where the subject will be further discussed.

"	Red and greenish gray sandstone, massive,	20	
"	*Red shale* (some olive),	19	
"	*Fish conglomerate. Pebbles of sandstone and limestone* (?) and *full of iron ore balls*,	2	
"	*Red shale* (some red sandstone layers),	31	
"	Red sandstone, massive (some greenish gray),	4	
"	*Red shale*, soft (a few sandy layers),	131	
"	Red sandstone, massive, (two or three *red shale* partings from 5′ to 10′ thick),	148	
"	*Red shale* soft and red sandstone massive alternating very regular in bands (5′ to 10′ each) complete exposure,	985	
"	Red shale and sandstone alternations (a few gray sandstones, streaked with red),	235	2106
VIIIg.	CHEMUNG and PORTAGE olive slate,	10	
"	Shale, olive and gray, and thin gray flags,	217	
	Section continues down to a total of VIIIg,		3314
VIII e.	Genesee,		560
VIII c.	Hamilton,		1131
VIII b.	Marcellus,		759
VI.	Lower Helderberg,		895
V.	Salina, Niagara and Clinton,		1080
IV.	Medina and Oneida,		2301

Hyner section.

XIII.	Lower Productive coal measures,		212
XII.	Pottsville conglomerate,		245
XI.	Mauch chunk red shale?		65
X.	*Pocono, upper, gray, sandstone,*	25	
"	Sandstone, etc., poorly exposed,	50	
"	" fine grained, greenish gray,	20	
"	" very fine, laminated, gray,	20	
"	Shale with sands, trace of red (poor exposure),	45	
"	Sandstone, flaggy, mottled, brownish,	75	
"	Shale with some fine grained gray flags,	90	325
X.	*Pocono, lower, red and olive sandstone* and shale,	20	
"	Sandstone, greenish gray, with shale,	70	
"	red and gray, alternate shale,	175	
"	red and some gray interbeds,	25	
"	greenish gray 15; red 20,	35	
	Concealed,	35	
"	Sandstone greenish gray (with red beds),	30	
	Concealed,	20	
"	Shale and red sandstone,	10	
	Concealed,	10	
"	sandstone, fine, greenish,	10	
	Concealed,	20	
"	Sandstone, fine, greenish,	10	
	Concealed,	10	
"	Sandstone *red*, fine, shaly,	30	
	Concealed,	30	
"	Sandstone, hard gray, mottled brown,	5	

	Concealed,	25	
"	Red shale and sandstone,	30	600
	Concealed above the well mouth,	30	
IX.	CATSKILL. Drive pipe in drift,	50	
"	Red rock with iron,	30	
"	Gray rock hard dark,	15	
"	Red rock partly shales,	22	
"	Gray rock with mica,	16	
"	Red rock hard,	5	
"	Red rock (salt water),	32	
"	"Copper," (salt water),	4	
"	Red rock (salt water),	10	
"	Gray rock (salt water),	16	
"	Red sandstone (gas),	46	
"	Red rock, with shales (gas),	52	
"	Gray rock, very hard,	11	
"	Red rock with gray shales,	115	
"	Sandstone,	4	
"	Red sandstone,	111	
"	Gray rock,	8	
"	Red shale, sandy (gas),	37	
"	Gray rock, dark, sandy band,	95	
"	Red rock (some oil),	35	
"	Gray shale, sandy,	35	
"	*Red shale* ("some ore"),	10	
"	Gray rock, with sand,	30	
"	*Red shale*,	7	826
VIII G.	CHEMUNG slates and shales bluish, alteranting with dark sandy bands (to bottom of well),*		1187

IX. Catskill in Lycoming County, G2, 49.

The valleys of Pine creek, Lycoming creek, and Loyalsock creek, are narrow and picturesque trenches a thousand feet deep cut down across the Allegheny mountain plateau from north to south, their almost vertical walls exhibiting nearly horizontal outcrops of the Pottsville conglomerate XII at the top; Mauch Chunk red shale, Ralston iron ore and Siliceous limestone XI, under it; Pocono gray sandstones and shales midway; and more or less of the Catskill red sandstones and shales along the bottom slopes, according to the depth of the erosion and the slightly waving dips. I give but one of the numerous sections to be seen in Mr. F. Platt's Report on Lycoming county, G2, because, the steep north dip along the front of the plateau

* Hyner's Run Oil Well record kept by Mr. James David. Other upper parts of this section were got from exposures between Hyner and Renovo stations on the P. and E. RR.

shows the bottom layers of IX; the whole *Transition series*, *IX–VIII;* and a considerable thickness of Chemung, VIII g.

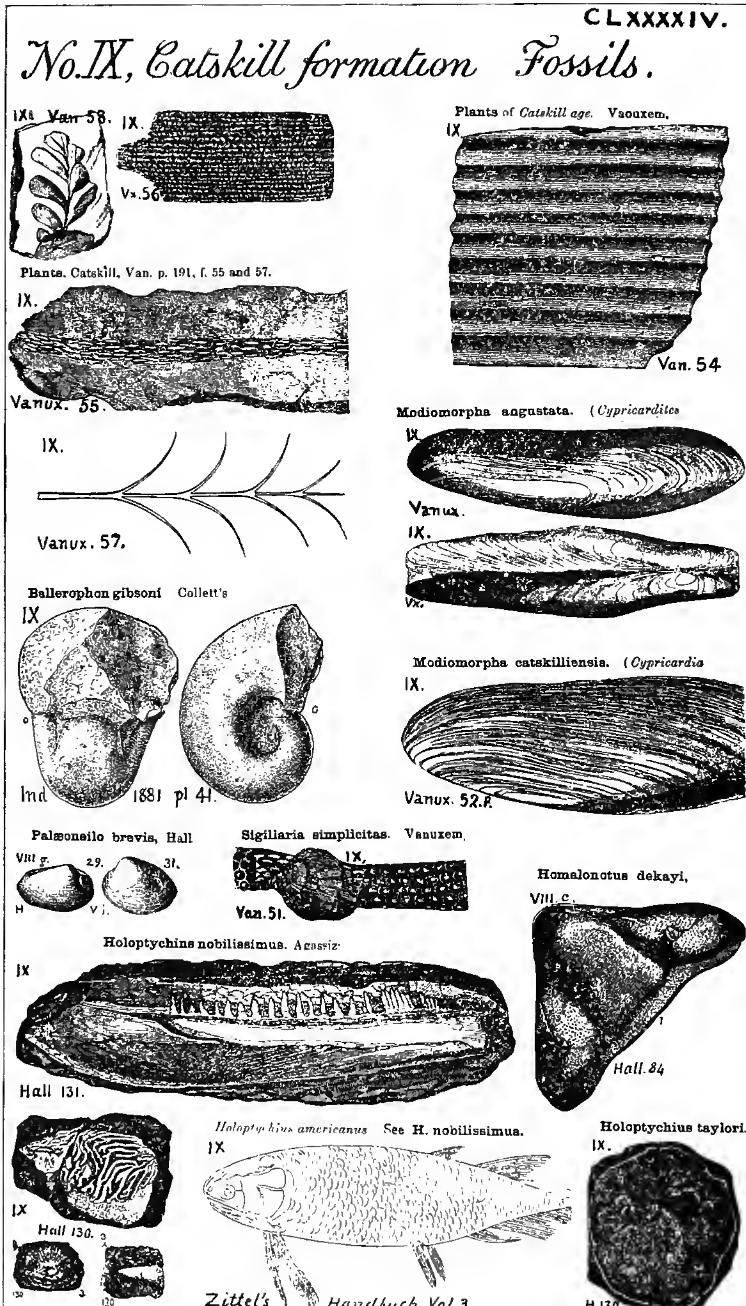
Loyalsock Bridge section.

IX, CATTSKILL *red shale*,	59	
" Red sandstone,	6	
" Red shale,	16	
Concealed,	95	
" Red shale,	10	
" Concealed,	4	190
IX–VIII. TRANSITION SERIES.		
" Gray shale and shaly sand,	51	
" *Calcareous* bed with *fossil shells*,	½	
" Gray shale and shaly sand,	16	
" Reddish shaly sandstone,	5	
" Gray shale,	5	
" Reddish and gray shaly sand,	4	
" *Mansfield iron ore*, with partings of *red shale*, and *fossil shells*,	2½	
" Reddish and gray shaly sandstone,	30	
" Gray shale and shaly sandstone,	36	
" *Calcareous* bed with *fossil shells*,	½	
" Gray shale,	8	
" *Calcareous* bed with *fossil shells*,	1	
" Gray shale and sandstone,	10	
" Gray shale with *fossil plant stems*,	6	
" Gray sandstone and shale,	4	
" Reddish sandstone and shale,	20	
" Gray shale and sandstone,	14	
" Reddish shale and sandstone,	10	
Concealed,	85	
" Red shale and sandstone,	12	
" Gray sandstone,	2	
" Red and gray shale alternations,	50	
" Gray sandstone,	9	
" Red shale,	5	
" Gray shale and sandstone,	4	
" Reddish shale and sandstone,	5	396
VIII g. CHEMUNG gray shale,	29	
" Gray sandstone,	12	
" Calc. rock with *crinoid stems*,	½	
" Gray sandstone,	6	
" *Calc. rock* with *fossil shells*,	3	
" Gray shale and shaly sandstone,	20	
" *Calc. rock* with *fossil shells*,	2	
" Gray shaly sandstone,	6	
" *Calcareous shale* with fossil shells,	1	
" Gray shales,	34	
" *Calc. rock* with *fossil shells*,	1	
" Gray shaly sandstone,	6	

"	*Calc.* beds with *fossil shells*,	$8\frac{1}{2}$	
"	Reddish sandstone and shale,	6	
"	*Calc. rock* and sandstone, fossil shells,	4	
"	Gray shale,	2	
"	*Calc. rock*, with *fossil shells*,	$\frac{2}{3}$	
"	Red and gray shale,	2	
"	*Calc. rock* with *fossil shells*,	$\frac{1}{2}$	
"	Gray shale and sandstone,	9	
"	*Plant stems in parting*,	—	
"	*Calc. rock* with *fossils shells*,	2	
"	Reddish, and gray shales and sandstones,	9	
"	Reddish shale,	12	
"	Gray shale,	26	
"	*Calc. rock* with *fossil shells*,	8	
"	Gray shaly sandstone,	18	
"	*Calc. rock* with *Spirifers*,	6	
"	Gray shaly sandstone,	20	
"	*Calc. rock* with *fossil shêlls*,	2	
"	Gray shaly sandstone,	60	
	Concealed,	100	
"	Gray shale and shaly standstone,	20	
	Concealed,	50	
"	Gray shaly sandstone,	20	506

To bottom of the exposure—in all, 1081.

This section is remarkable for the presence in it of 16 *calcareous breccias* containing numerous well known Chemung shells; which fact does not necessarily remove the series from the Catskill formation. It is also remarkable for an almost entire absence of the *plant beds* so abundant at this horizon in Bradford and Susquehanna counties.


CLXXXXIV.
No. IX, Catskill formation Fossils.
Plants of Catskill age. Vanuxem.
Van. 54
Plants. Catskill, Van. p. 191, f. 55 and 57.
Vanux. 55.
Vanux. 57.
Modiomorpha angustata. (Cypricardites
Bellerophon gibsoni Collett's
Ind 1881 pl 41.
Modiomorpha catskilliensis. (Cypricardia
Vanux. 52.
Palæoneilo brevis, Hall
Sigillaria simplicitas. Vanuxem.
Van. 51.
Homalonotus dekayi,
Hall. 84
Holoptychius nobilissimus. Agassiz
Hall 131.
Hall 130.
Holoptychius americanus See H. nobilissimus.
Zittel's Handbuch Vol. 3
Holoptychius taylori.
H. 130

CHAPTER CX.

Fossils of the Catskill age.

The undoubted Catskill red rocks are almost destitute of remains or traces of animal life. A few shells have been mentioned in preceding pages, and the fish teeth and scales of *Holoptychius nobilissimus* (*americanus*) and *taylori*, are given (reduced) on plate CLXXXXIV. *Dypterus sherwoodi*, Newberry, can be seen figured in S. A. Miller's N. A. G. & Pal. p. 596.

Plant remains are abundant in the Catskill strata, but usually in such a decayed condition from long floating before coming to rest at the sea bottom, that their specific characters cannot be made out. Three or four published by Vanuxem are shown on plate CLXXXXIV. *Aneimites* (*Noeggarathia*, *Archæopteris*) *obtusus* a fern closely allied to the Carboniferous genus *Cyclopteris*, described by Lesquereux and Dawson, may be seen (reduced) as the first figure on page 1384 above, among figures of Chemung fossils, but so high in the Chemung that it may be accounted a Catskill form. The same is true of *Archæopteris hybernica*, a fine fern, large and very perfect specimens of which have been collected at the Meshoppen quarries in Wyoming county, and at Honesdale in Wayne county. See figures of both in Miller, p. 105, 107.

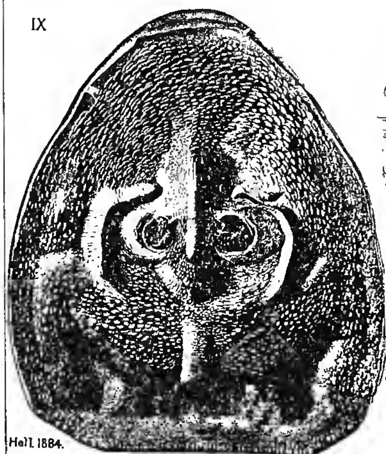
Crinoidal fragments are abundant in many of the thin layers between the sandstones, and must have been carried by currents from distant and extensive fields of stone-lilies; as happened to a large extent in the following Carboniferous age. *Cystideans* however had already become extinct.

Brachiopod shells, chiefly species of the genus *Spirifera*, are very abundant at several thin horizons. Very few *Lamellibranch* shells have been seen, although of so many genera and species and abundance in Chemung rocks. Some great change must have occurred in the character of the sea, or geographical relations of its shores to the open water. It has already been said that the only shell found by Ste-

CLXXXV.

No. IX, Catskill fossils, continued.

Stylonurus excelsior, Hall.

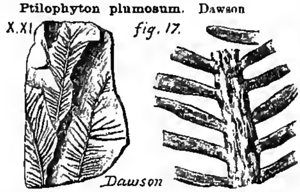


Hall (Pal.NY Vol VII, p. 156, 221, plate 26) 1888, reduced.

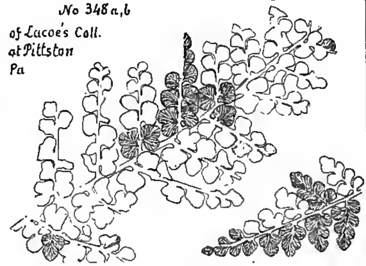
Stylonurus excelsior Hall

No. X, Pocono, or Lower Carboniferous fossils.

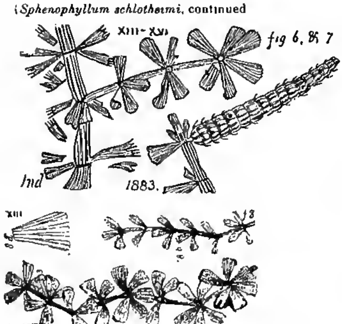
Ptilophyton plumosum. Dawson



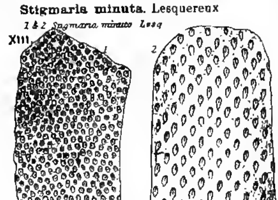
Pseudopecopteris obtusiloba, (*Sphenopteris*



(*Sphenophyllum schlotheimi,* continued



Stigmaria minuta. Lesquereux



Sidling Hill, Huntingdon Co., Pa. (T3, 88), venson in the whole mass of Catskill rocks in the Bedford county was one lamellibranch *Amnigenia catskillensis*, and that near the top of the formation; it was found by Vanuxem in the Catskill mountains in eastern New York and called by him *Cypricardia catskillensis*. Hall figures it under the name *Modiomorpha catskillensis* (see plate CLXXXXIV.) *Modiomorpha angustata* and *Palæoneilo brevis* are two other Catskill species. A gasteropod shell *Bellerophon gibsoni* occurs, but is rare.

Crustaceans, so abundant in the foregoing ages, are represented by only one large species of trilobite, *Homalonotus dekayi*, which lived in great numbers; and by a remarkable and very large creature called by Hall *Stylonurus excelsior*, described and figured in his Pal. N. Y. Vol. VII, p. 156, 221, plate 26 (reproduced on a reduced scale on p. plate CLXXXXV above).

Fishes are only known in the Catskill and Catskill-Chemung by scattered teeth and broken scales and bones, which, however, are in such abundance at various horizons as to make the *fish bone beds* described in foregoing pages, especially in chapter 97, p. 1453. The *Holoptychius nobilissimus* described by Agassiz from the Old Red formation of Scotland is apparently the same with our Catskill *Holoptychins americanus*. Our *H. taylori* seems a differrent species. See Hall's figures reduced on p. plate CLXXXXV above.*

*The prodigious number of fish remains found along special horizons in the lower part of the Catskill formation requires some explanation. Fish epidemics and volcanic eruptions have been suggested. But there seems to be a simpler hypothesis, based on the possible shallowness of the Devonian sea.

Lesquereux describes the Eocene shales of Florissant in Colorado, and Saporta those of the southwest of France in such a way as to throw light on similar deposits of a much earlier age. Saporta thinks that thermal springs and volcanic eruptions in the ancient French lakes destroyed the fish periodically; shoals of them lying dead on the muddy bottom, and being carefully and rapidly covered. One of many genera, the *Lebias*, still lives in fresh water in Sardinia and northern Africa. Swarms of flies, musquitoes, butterflies, libellules, winged ants and bees were as perfectly preserved, with leaves, flowers, fruits and branches from the neighboring shore.

Lesquereux describes the Florissant shale as thin laminæ of mud covered with branches, leaves, seeds, flowers, pistils and stamens, insects and fish, in immense numbers, and small feathers of birds. Similar shales are found at

Green river station, Elko, the mouth of White river, etc. No evidence of cataclysmic violence or abnormal influences appears. The shales are of fine sand, 2 to 5 mm. thick, all covered on their upper surfaces with the various remains mixed together. They represent annual mud deposits of the spring time, dried and hardened in summer, upon which the living things fell and remained. The leaves are not crumpled, folded or rolled, but flat as they dropped from the air. In the Green river fish beds, there is a rich deposit 8′ to 10′ thick of these alternate layers between which prodigious numbers of fish have been preserved. No doubt in the summer droughts, nothing remained of the lake but isolated pools overcrowded with fish, which of course perished when the pools themselves dried up. These pools were probably swampy lagoons of various depths, sizes and shapes, so that some remained always as open water and their fish were not destroyed.

The history was a long one. At Green river station 600′ of such shales are visible. In Devonian times only the shallow marshy lagoon-bordered shore of the sea furnished proper canditions for such adventures; and such a shore, although very extensive, might now be hard to find, for it may be deeply concealed, or it may have been eroded; but in point of fact it has been partially preserved, and is partially exposed by the erosion of the continent. Possibly there was such a shore in all stages of the Devonian age; certainly there was such a shore in its early stage, and there we find the Catskill fish beds. The later shore deposits have probably been swept away; our middle and upper Devonian sandstones and shales, with only occasional scattered fish remains, represent then the deeper sea deposits. The discovery of *Holoptychius* in the Chemung, described by Prof. Claypole, and in the fish beds of the Mansfield Chemung-Catskill in Tioga county show that the Catskill conditions were merely the coutinuation of the natural history of the preceding age or ages. Proc. Am. Philos. Society.

Prof. Cope, while agreeing in general with these remarks, considered it dangerous to trust too implicitly to the *scales* of Devonian fish for determining their specific identity at such different horizons. But I see no objection to the continuance of the same species through any height of the column where there is no good evidence of any physical break in the series of deposits.

END OF VOL. II.